THE ENGINEER

A Seven-Day Journal

H.M. Submarine "Affray"

On Wednesday afternoon of last week, the Parliamentary and Financial Secretary to the Admiralty, Mr. James Callaghan, in reply to questions concerning the salvage operations of H.M. Submarine "Affray," stated in the House of Commons that diving had been possible only on fifteen of the forty-seven days since the wreck was found. Divers could work only for one hour in twenty-four at the depth and in these tides, and the submarine, which had now settled with a list of 50 deg., caused some delay when it became temporarily unstable. Continuing, Mr. Callaghan said that, apart from the snort, an external examination of the hull had revealed no other damage to hydroplanes, rudder or asdic dome, hatches were shut and torpedo tube doors closed. The interim report of the Naval Board of Inquiry, he stated, showed that metallurgical tests upon parts of the broken snort had revealed that the metallurgical condition of certain members was below standard and that the welding was suspect. As a result of this report, the snort tubes of "A" class submarines were to be replaced and a ban placed upon the use of the device until the work was completed. Referring to the question of salvage, Mr. Callaghan reminded the House of the hazardous diving conditions and the difficulties involved in working at great depths, and went on to say that although the prospects of raising a flooded submarine, weighing about 1000 tons, through 300ft were not good, no final decision on salvage had been taken.

The British Association

The 113th meeting of the British Association for the Advancement of Science opened in Edinburgh on Wednesday evening last, and will continue until Wednesday next, August 15th. The meeting, which is being held under the presidency of H.R.H. The Duke of Edinburgh, K.G., F.R.S., is the Association's sixth assembly in Edinburgh, the former occasions being in 1834, 1850, 1871, 1892 and 1921. The large company of members attending this year's meeting assembled in the McEwan Hall on Wednesday evening, when the Royal President received from the University of Edinburgh the Honorary Degree of Doctor of Laws. The degree was conferred by the Chancellor of the University, the Marquess of Linlithgow, K.G. After the ceremony, the Association was welcomed to the city by the Right Hon. James Miller, Lord Provost of Edinburgh, and Sir Edward Appleton, F.R.S., Principal of the University. H.R.H. The Duke of Edinburgh then delivered his Presidential Address, entitled "The British Contribution to Science and Technology in the Past Hundred Years." An abstract of the address is printed on page 176 of this issue. The sectional meetings of the Association began on Thursday morning. Those of Section G, Engineering, are taking place, under the presidency of Sir Claude Gibb, F.R.S., in the Heriot-Watt College. Sir Claude's Presidential Address, which he is delivering this, Friday, morning is entitled "Two Thousand Years of Engineering."

Accident on the Southern Region

On Sunday last, August 5th, eight people were killed and forty-seven were injured in a train accident at Ford, near Arundel, on the Southern Region of British Railways. The two electric trains involved were the 10.47 a.m. train from Three Bridges to Bognor and the 11.17 a.m. excursion train from Brighton to Portsmouth. The Bognor train was standing in Ford Station, just before mid-day, when the Portsmouth train ran into its rear. Reports state that the rear coach of the Bognor train and the first coach of the Portsmouth train were telescoped, several compartments of the latter train being shorn off. The rear coach of the Bognor train was ripped from its bogies and tilted over the station platform, a hole being torn in its roof by the girders of a signal gantry at the end of the platform. According to press statements, the Portsmouth train had been halted by signals outside the station and, when it started, passed at slow speed over some points before colliding with the rear of the stationary train. Amongst those killed were the driver of the Portsmouth train, and the day after the accident another of the passengers died, bringing the death roll to nine.

Standard Aerodrome Lighting System

A guide to the efficient design of modern land and water aerodromes suitable for the needs of international air traffic, is contained in the International Civil Aviation Organisation's (I.C.A.O.) international standards and recommended practices for aerodromes, just adopted by the Council of I.C.A.O. in Montreal. These standards and recommended practices, which are now Annex 14 to the Convention on International Civil Aviation, prescribe the physical and associated characteristics and equipment to be provided at aerodromes. The new standards pay particular attention to the question of day and night marking of aerodromes and to the provision of visual aids for aerodrome location, and for approach, landing, taxi-ing and take-off purposes. Specifications are included for aerodrome identification signs and beacons, runway and taxiway markings, runway and taxiway lights, channel lights for water aerodromes, obstruction marking and lighting and low intensity approach lighting. Specifications are set for the various colours which are used for lights (red, blue, yellow, green and white) and surface markings (red, orange, white and black), as only by standardising the chromatic limits of the lights used can pilots always be sure that there will be no confusion in identifying the various colours. At present I.C.A.O. membership consists of fifty-seven nations, which operate more than 90 per cent of the world's international civil air transport. Unless a majority of them disapproves before November 1, 1951, the annex will come into force on January 1, 1952, for all regular and alternate aerodromes used by international scheduled air services.

Electricity Supplies for Industry

At the beginning of this year the Association of British Chambers of Commerce set up a committee of experts, under the chairmanship of Mr. Harry Yates, a director of Colvilles, Ltd., to study the whole subject of electricity supplies for industry. This week the Association has published the committee's report, copies of which have been sent to the Chancellor of the Exchequer and the Minister of Fuel and Power. In a letter accompanying the report, the Association has stressed the urgent need for increased capital expenditure if the British Electricity Authority is to be expected to narrow the dangerous gap between electricity demand and supply. Four principal recommendations are made in the report, the first of which is that the B.E.A. should ensure that nothing less than the highest planned rate of commissioning of new plant should, in practice, be the aim. The second recommendation is that there should be a suitable system for warning industry of impending power cuts, the report saying that "to reduce to a minimum the spoiling of valuable materials and products and because of the value of 'ripple' and other controls as a warning system and a demand regulator, every possible means should be pressed for overcoming the technical and other objections to these as soon as possible." Thirdly, it is urged that industrial load-spreading arrangements in co-operation with industry and commerce should be more widely extended and, finally, that supplies of solid fuel for domestic space heating should be assured for coming winters as a major contribution to conserving electricity supplies during peak periods.

The World Power Conference

The annual report of the World Power Conference for the year 1950 has now been published. It deals with the organisational changes which were effected during the year and notes that Sir Harold Hartley, F.R.S., assumed office as president at the close of the fourth World Power Conference, which was held in London in July, 1950. The report also includes a "brief chronicle" of the events of that conference, which was the first plenary meeting to be held since 1936. It was attended by 1629 delegates, representing fifty-three different countries, and 156 papers were presented for discussion by twenty-eight national committees. The international executive council of the World Power Conference has decided unanimously to accept an invitation from the Brazilian national committee to hold a sectional meeting in Rio de Janeiro in July, 1954. It will be the first occasion on which a World Power Conference has met in South America and it is expected that the subject to be discussed will centre round the special power and fuel problems of the tropical and sub-tropical countries. The international executive council has decided also to admit the German Federal Republic and Japan as members of the Conference.

The British Welding Research Association

The annual report of the British Welding Research Association for the year ending March 31, 1951, the fifth year of the Association's existence, was presented recently by Sir Charles Lillicrap, chairman of the council. As evidence of the growing interest in the Association's work, the report recorded an increase in membership, which is now made up of 214 ordinary members and eighteen associate members, compared with 196 and thirteen, respectively, a year ago. The various research activities during the year were under the guidance of some thirty committees and forty-nine meetings were held by the various technical committees and panels, whose activities were briefly reviewed in a section of the report. Out of a total income of £80,605, during the year under review, the expenditure on researches was £47,008, the main items being £6338 on the behaviour of welded structures under dynamic loading, £5971 on the load-carrying capacity of frame structures, £5171 on stresses in welded pressure vessels, £3089 on the constitution of weld metal and £2867 on the fusion welding of aluminium alloys. The principal Ministry of Supply contracts included £3758 on the spot welding of light alloys and £4629 on high tensile weldable structural steels. Reference was made in the report to the project for building, at the association's research station, a permanent laboratory to house a 100-ton Losenhausen fatigue machine and complementary equipment for researches on fatigue strength.

The Bhakra-Nangal Project in the Punjab

A LARGE multi-purpose project, intended both for irrigation and hydro-electric power generation, is at present under construction in India on the River Sutlej, in the Punjab. The work will include a gravity dam, 680ft in height, at Bhakra, with two power stations immediately below it. Further down the river there is a second dam under construction, the Nangal dam, including intake works to the main feeder canal supplying a large area—eventually some 6½ million acres—with irrigation water. The main canal will have two power stations along its length.

An idea of the importance of the project may be given by the fact that the production from the land irrigated by the scheme is estimated at 1·13 million tons of food grains. By comparison, India's annual shortage is expected to vary between 2 and 4 million tons, depending on climate and crop disease. On the other hand, the power which can be generated continuously is 400MW. It is pointed out that the wealth which results from the project is difficult to convert into terms of money, but a broad survey leaves the impression that in a single year of full operation it will surpass the total capital outlay.

The accompanying illustrations show a plan and cross section of the dam, which will be built in the Bhakra gorge, where the River Sutlej pierces the last range of hills before entering the plain. It is a straight gravity structure, 680ft in height above the foundation, and about 1700ft long along the crest. The storage capacity of the reservoir which it forms will be 7·4 million acre-feet, of which 5·7 million will be useful storage. The reservoir will extend for some 56 miles upstream, with a width of about 1½ miles and a surface area of 38,000 acres. It is fed by a catchment 22,000 square miles in area. Some hydrological data at the dam site are given in the accompanying table.

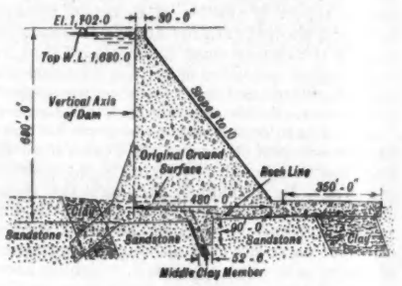
Hydrological Data of the River Sutlej at Bhakra

Annual run-off (average 1912–42)	13,460,000 acre-feet
Maximum annual run-off (1912–42)	20,060,000 acre-feet
Estimated peak flow at site	390,000 cusecs
Discharge capacity at dam :	
T.W.L. 1685ft	419,000 cusecs
T.W.L. 1680ft	355,200 cusecs
Minimum river flow	3000 cusecs
Elevation of stream bed at dam site	1143ft
Average annual silt load	19,600 acre-feet

During construction the River Sutlej will be diverted through two diversion tunnels, each 50ft in diameter, one on each side of the river. There will be two power stations, one on each bank of the Sutlej, close to the toe of the dam. The left bank power-house will be built first and will contain four turbo-alternator sets, each of 84MW. The right bank power station will be underground in a tunnel 500ft long, 80ft wide and 140ft in height; eventually it will contain eight 84MW sets, which will be installed successively as the demand for power grows. The net head will vary between 512ft and 268ft, Francis turbines being employed. Each machine will be supplied by a penstock 15ft in diameter.

There will be a spillway channel at the centre of the dam, controlled by two drum gates, each 110ft by 28ft, and twenty-four outlets in the body of the dam. The maximum discharge capacity of this spillway will be 265,000 cusecs, with a top water level of 1685ft, which is an exceptionally high flood level, the level of the spillway crest being 1652ft. The spillway is 250ft in width, with a hydraulic jump apron 480ft in length at the toe. In addition, there will be a second spillway consisting of two radial gates, each 50ft by 50ft, incorporated in the crest of the dam near the left bank and connected to the left bank diversion tunnel, as shown in the accompanying illustration. The combined capacity of the two spillways, with the maximum level given above, will be in excess of 400,000 cusecs. The thousand-year peak flood of the Sutlej is estimated at 330,000 cusecs, and the maximum flood recorded is 390,000 cusecs, estimated from flood marks in the gorge area of the flood in 1875.

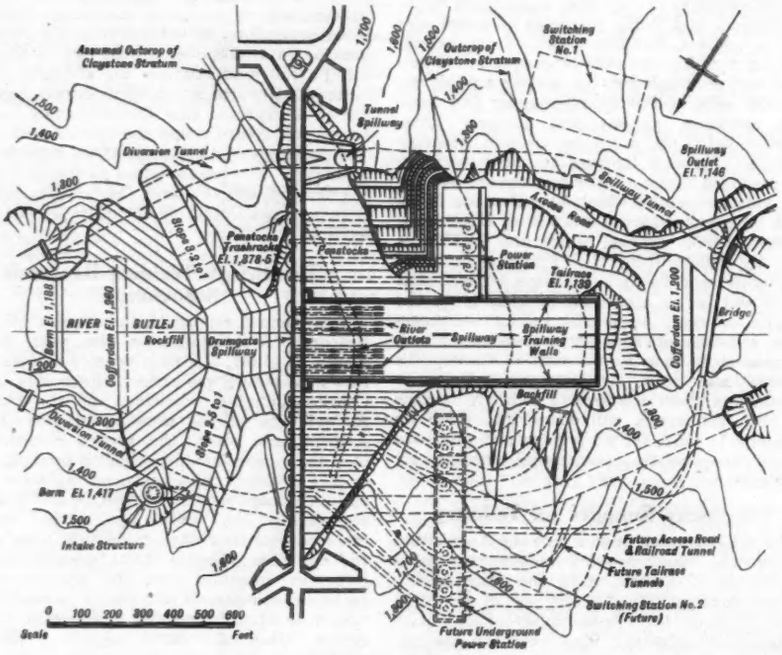
These figures fixed the maximum capacity required, the choice of two different kinds of spillway being arrived at both for reasons of safety and economy, the capacity of the first is the largest that could be obtained within the narrow width of the gorge, and the provision of the two means that if flood damage to one of the spillways occurs, the second one will be available whilst repairs are being carried out, the probability curve indicating that the capacities of the two spillways correspond to the twenty-three-year and the yearly flood respectively. As is well known, the spillway design of a dam of the height of the Bhakra dam is of crucial importance and presents many difficulties. Twenty-five alternative arrangements were investigated in the design of the Bhakra spillways, which were the subject of two papers presented at the Fourth Congress on Large Dams,* which give a detailed account of the design problems and the extensive model tests carried out to solve them and to study related problems such as the sedimentation of the reservoir.



CROSS-SECTION OF BHAKRA DAM

In the early stages of development, when the number of power units may be smaller than the total of four in the left bank power station, the flow from the tail-race may not be sufficient to meet the maximum irrigation requirement of 23,000 cusecs. For this reason, as well as to increase the spillway capacity and provide scour pipes, twenty-four river outlets have been provided in the spillway section of the dam, in sets of eight at three different levels. They are shown in the cross section through the central spillway; each one will be equipped with a 96in jet flow gate, giving a total flood discharge capacity of 102,500 cusecs, assuming one unit at each level is not operating. This figure for discharge is included in the capacity of 265,000 cusecs given above for the central spillway. In addition, the right bank diversion tunnel will be used as an alternative outlet, and an intake shaft with a maximum capacity of 32,000 cusecs and a minimum of 23,000 cusecs at the low reservoir level of 1440' will be constructed to lead into the tunnel, regulated by five 96in valves and gates, the tunnel being plugged at its upstream face.

At the present time the work of driving the diversion tunnels at the Bhakra dam site is well advanced, after completion of very extensive preliminary works involving the provision of road and rail access to the

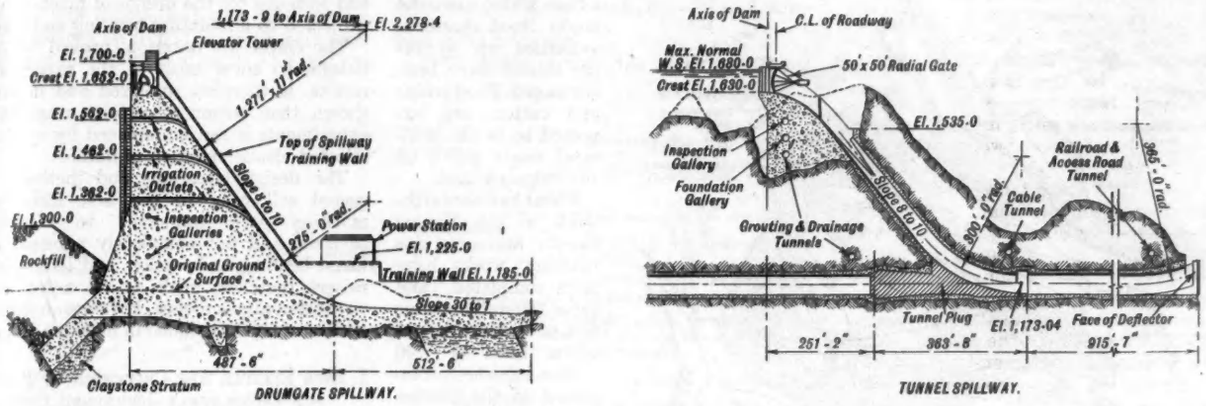


BHAKRA DAM

* Fourth Congress on Large Dams, New Delhi, 1951, Question No. 12. Paper R.99, "Selection of Type, General Arrangement and Details of Spillways and Determination of Their Capacities, with Reference to the Bhakra Dam Project," by Sardar Sarup Singh, Sardar A. S. Kalha and Sardar R. S. Gill. Paper R.102, "Hydraulic Model Study of Spillway and Tunnel of Bhakra Dam" by Dr. H. L. Uppal.

dam site, and site accommodation. It is estimated that the tunnels will be completed by the spring of 1952, when excavation for the foundations of the dam will be started; completion of the dam is expected in 1956.

The tunnels are each of 50ft finished diameter, the excavated diameter being about 60ft, and are each about half a mile long. They have been designed for a maximum flood discharge of 275,000 cusecs with a velocity of the order of 50ft per second, and



SPILLWAYS OF THE BHAKRA DAM

—operated from the superstructure. Since the maximum design flood can be passed at a top level of 1140, a breast wall is constructed above this level to provide the necessary storage capacity. This arrangement is shown in the cross section, which also shows the scour protection on the downstream side, and the assumed position of the standing wave corresponding to the maximum flow.

The canal intake on the left bank consists of a regulator of eight 24ft bays, capable of taking 14,500 cusecs altogether, including 2000 cusecs for the silt ejector. The two left-hand bays of the main barrage have a crest level of 1107 to accommodate the shingle excluder, which consists of six tunnels facing the lines of flow into the head regulator. An extensive system of drainage pipes and drainage and inspection galleries is provided, including a clay puddle wall upstream and a downstream filter consisting of 3ft of gravel and sand under the downstream curtain wall.

The Nangal dam is at present approaching completion, the work having been in progress since the end of 1946. It was built in two halves, each in the shelter of a cofferdam. As the work proceeded the degree of mechanisation was gradually increased and the constructional methods modernised, so that a better rate of progress was achieved. Compressed air equipment has been used extensively on the project, for the first time in the Punjab. The numerous hydraulic model studies for the design of the dam were carried out at the Indian Hydraulic Research Laboratory.

pass through sandstone and claystone strata of the Nahan series, which vary considerably in nature. (The dam itself is to be located on the largest member of the sandstone series.) Pilot tunnels were first driven, drilling and blasting being done with pneumatic hammers and high explosives, and mucking by manual labour, with narrow-gauge skips. Before enlargement of the tunnels was started flood protection works were constructed in front of all four of the tunnel portals. Enlargement to the full section is at present in progress, the rate of progress of the pilot tunnels having been about 10ft a day, and of the enlargement 5ft or 6ft a day.

The excavation at the dam site will be carried to sound rock except within the claystone strata, where it will be taken down to varying depths below the sandstone. The claystone stratum directly upstream is to be excavated and backfilled with concrete, which will both carry the loads from the dam across the claystone, and confine it so that it can withstand the load. It will be further protected with rockfill up to a level of 1300. The estimated quantities for the dam are about 3 million cubic yards of excavation and 5·12 million cubic yards of concrete.

Nangal Dam

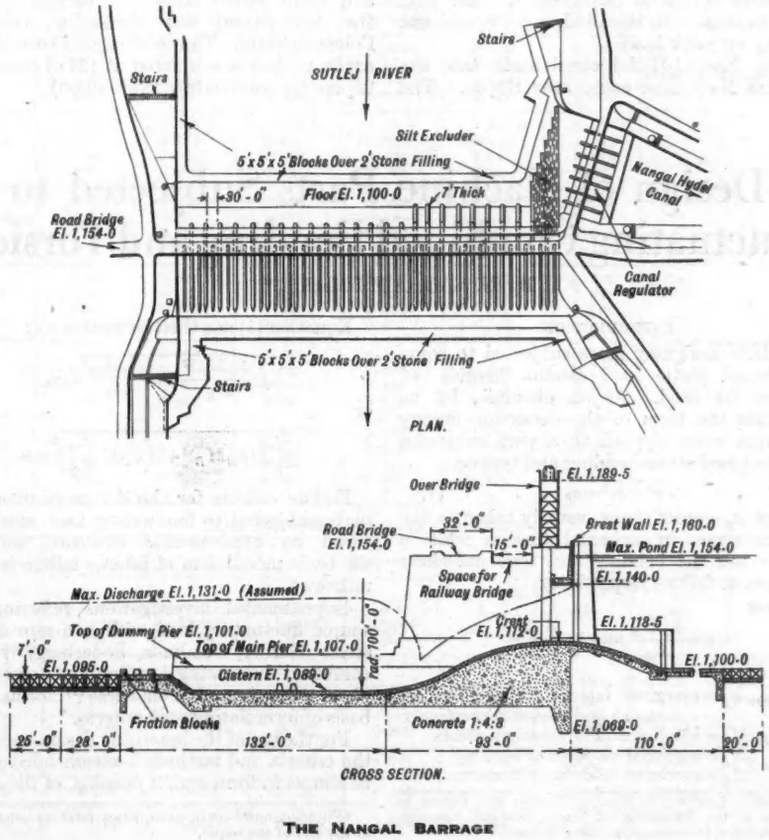
The Nangal barrage is situated about 8 miles downstream of the Bhakra dam. It is primarily intended to supply the Nangal-Hydel canal on which two power stations with a total installed capacity of 144MW are situated, and from which the Bhakra main line canal leads the irrigation waters to the Punjab.

The barrage provides sufficient storage for one day's (24,000 acre-feet) consumption of irrigation water, and will thus even out the daily fluctuations of the discharges from the Bhakra dam. It consists of twenty-six bays, each with a clear opening of 30ft, separated by piers 7ft wide, giving an overall length of 955ft. The total height of the barrage is 95ft.

The accompanying illustration shows the barrage in plan and cross section. Each of the openings has two gates to facilitate regulation—one 12ft and the other 16ft in height

The Canal Network

The principal canals in the proposed irrigation network served by the project are shown in the diagram overleaf, which also indicates the extent of the area supplied.

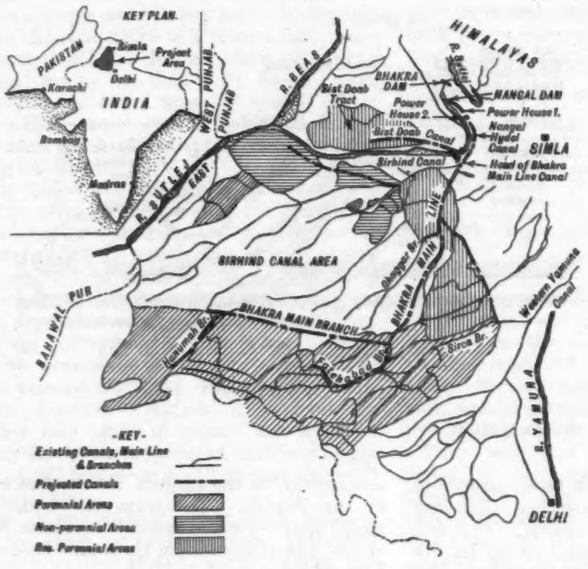


THE NANGAL BARRAGE

The Nangal-Hydel canal is about 40 miles in length, and traverses difficult country, involving substantial earthworks, with embankments up to 75ft in height, and many subsidiary works. The canal will be lined with concrete throughout its length. It is 92ft wide at bed level, the normal depth of water being about 20ft, with side slopes of 1¼ : 1, and normally a slope of 1 in 10,000.

The two power stations are situated 12 and 18 miles from the intake respectively, each utilising a head of about 100ft and having installed three 24MW units. Each one will have a stepped spillway capable of taking the entire flow, although it is proposed in the later stages to run them as base load installations, with the Bhakra power stations taking up peak loads.

The Nangal-Hydel canal leads into the Bhakra Main Line canal near Rupar. The latter will be a lined channel 108 miles in length and will feed a vast network of subsidiary canals, including existing canal systems which will be remodelled in many cases. The total length of the main canal and branches of the Bhakra system is intended to be 539 miles, of which 303 miles will be lined. Distributaries and minor canals, all unlined, will total 2100 miles in length. The earthen channels have been designed for non-silting non-scouring velocities while, in the larger lined channels, velocities up to 6ft per second have been envisaged. Food grains and cotton are expected to be the principal crops grown on the irrigated land.



MAIN IRRIGATION CANALS

About half the earthwork in the Nangal canal and various masonry works have been completed, and some 250 million cubic feet of earthwork, out of a total of 700 million have been completed on the Bhakra canals.

The design of the entire Bhakra-Nangal project has been carried out by the Irrigation Department of the Public Works Department of the Punjab, under the direction of the chief engineer, Sardar Sarup Singh. Some of the design work of the Bhakra dam was, however, done in the United States, where engineers of the Irrigation Department collaborated with the International Engineering Company, Inc., Denver, Colorado, and where model tests were carried out at the Agricultural and Mechanical College, Colorado State. The total capital cost of the entire project is estimated at 127·3 crores of rupees (approximately £95 million).

Design of Machine Parts Subjected to Fluctuating Combined Bending and Torsion

By N. SAG, A.M.I.Mech.E.*

Introduction

WHEN designing parts subjected to combined static load elastic theories of failure are used. As an example, let us examine the form of the distortion energy criterion when applied to a part subjected to combined static bending and torsion :

$$\sqrt{\sigma^2+3\tau^2}=\sigma_p \quad . \quad . \quad . \quad . \quad (1)$$

Where σ_p=proof stress, usually taken as the failure stress in uni-axial tension while σ and τ are the bending and torsional shear stresses at failure respectively.

Thus

$$\sigma=\frac{\phi_B M_B}{Z_B} \text{ and } \tau=\frac{\phi_T M_T}{Z_T}$$

where

ϕ_B, ϕ_T=marginal factors for the bending moment and torque respectively.
M_B, M_T=bending and torsional moments.
Z_B=sectional modulus of bending
Z_T=sectional modulus of torsion.

Equation (1) can then be written as :

$$\sqrt{\frac{(\phi_B M_B)^2}{Z_B}+3\frac{(\phi_T M_T)^2}{Z_T}}=\sigma_p,$$

or

$$\frac{1}{Z_B}\sqrt{(\phi_B M_B)^2+3\left(\phi_T M_T\frac{Z_B}{Z_T}\right)^2}=\sigma_p.$$

Failure criteria for the design of machine parts subjected to fluctuating load must be based on experimental evidence because the basic mechanism of fatigue failure is still unknown.

Experimental investigations referring to simple fluctuating load with non-zero mean stress (Gerber, Goodman, Soderberg)[3]† and combined fluctuating bending and torsion in phase (Gough and Pollard)[1], [2] forms the basis of formulating such criteria.

For the use of the practising design engineer the criteria and methods recommended must be simple in form and, if possible, of the same kind as the simple equations used for combined static load.

Fatigue failure cannot be accurately expressed by any single elastic criterion of failure. However, by a critical survey of experimental results, especially those published by H. J. Gough,[2] it is possible to use existing elastic criteria in a modified form which will cover with sufficient accuracy a wide range of materials used in design.

The object of this report is to carry out this survey and to develop rational methods and formulæ for the design of machine parts subjected to fluctuating bending and torsion.

The ellipse arc criterion, proved by H. J. Gough, to cover most of the experimental results, is therefore analysed and it will be shown that within a certain range of the experiments it can be replaced by a suitably selected elastic criterion of failure.

The design equations and methods suggested will refer in the first instance to machine parts subjected to completely reversed and not completely reversed combined bending and torsion, and having stress raisers (notches) such as oil holes, fillets, circumferential grooves, keyways and splines which cannot be avoided in machine design.

I. The Ellipse Arc Criterion of Failure for Completely Reversed Combined Bending and Torsion

(1) Gough in his paper[2] recommends the use of an ellipse arc criterion of failure for ductile materials with stress raisers (notches) and for brittle materials with and without notches subjected to combined fluctuating bending and torsion.

Denoting the nominal cyclic stresses at failure due to bending and torsion calculated by the engineering formulæ by $\pm\sigma_c$ and $\pm\tau_c$ respectively, and the corresponding endurance limits for bending only and torsion only by $\pm b$ and $\pm t$ respectively, the ellipse arc criterion of failure for completely reversed stresses is expressed as follows :—

$$\left(\frac{\tau_c}{t}\right)^2+\left(\frac{\sigma_c}{b}\right)^2\left(\frac{b}{t}-1\right)+\left(\frac{\sigma_c}{b}\right)\left(2-\frac{b}{t}\right)=1 \quad . \quad (2)$$

If the endurance limit of the material without notch is $\pm\sigma_{er}$ and $\pm\tau_{er}$ in bending only and torsion only, then

$$t=\frac{\tau_{er}}{k_{fT}} \text{ and } b=\frac{\sigma_{er}}{k_{fB}},$$

where k_{fT} and k_{fB} are the appropriate strength reduction factors for the material in torsion and bending respectively.

Thus the ellipse-arc criterion can be rewritten, resulting in :

$$\left(\frac{k_{fT}\tau_c}{\tau_{er}}\right)^2+\left(\frac{k_{fB}\sigma_c}{\sigma_{er}}\right)^2\left(\frac{k_{fT}}{k_{fB}}\frac{\sigma_{er}}{\tau_{er}}-1\right)+\left(\frac{k_{fB}\sigma_c}{\sigma_{er}}\right)\left(2-\frac{k_{fT}}{k_{fB}}\frac{\sigma_{er}}{\tau_{er}}\right)=1 \quad . \quad . \quad (2a)$$

However, if the bending and torsional stresses are completely reversed, $k_{fB}\sigma_c=\sigma$ and $k_{fT}\tau_c=\tau$ represent the actual maximum bending and torsional stresses in the notched specimen, and thus, multiplying (2a) by $(\sigma_{er})^2$ we obtain :

$$\tau^2\left(\frac{\sigma_{er}}{\tau_{er}}\right)^2+\sigma^2\left(\frac{k_{fT}}{k_{fB}}\frac{\sigma_{er}}{\tau_{er}}-1\right)+\sigma\cdot\sigma_{er}\left(2-\frac{k_{fT}}{k_{fB}}\cdot\frac{\sigma_{er}}{\tau_{er}}\right)=\sigma_{er}^2. \quad . \quad (2b)$$

The preceding equation can be rearranged and written as :

$$\left.\begin{aligned} &A_1\sigma+\sqrt{A_2\sigma^2+A_3\tau^2}=\sigma_{er} \\ \text{or} \quad &\frac{\sigma}{\sigma_{er}}=\frac{1}{A_1+\sqrt{A_2+A_3(\tau/\sigma)^2}} \end{aligned}\right\} \quad . \quad (3)$$

* Senior Lecturer in Machine Design and Officer in Charge of the Experimental Stress Analysis Research Laboratories, Melbourne Technical College.

† Superior numbers in parentheses refer to references at the end of the paper.

where

$$\left.\begin{aligned} A_1 &= 1-\frac{1}{2}\frac{k_{fT}}{k_{fB}}\cdot\frac{\sigma_{er}}{\tau_{er}} \\ A_2 &= \left(\frac{1}{2}\frac{k_{fT}}{k_{fB}}\frac{\sigma_{er}}{\tau_{er}}\right)^2 \\ A_3 &= \left(\frac{\sigma_{er}}{\tau_{er}}\right)^2 \end{aligned}\right\} \quad . \; . \; (4)$$

(2) *The* σ_{er}/τ_{er} *Ratio.*—The values for σ_{er} and τ_{er} as obtained experimentally by Gough and his collaborators are plotted in Fig. 1, as a function of the ultimate strength. For ductile materials these curves can be replaced up to 65 tons per square inch ultimate strength by a straight line passing through the origin and resulting in a constant (average) ratio $\sigma_{er}/\tau_{er}=1{\cdot}7$. The data on brittle materials are scarce and for the available points the average $\sigma_{er}/\tau_{er}=1{\cdot}15$. The range of the actual σ_{er}/τ_{er} ratios and the percentage error by using the average value is also indicated in Fig. 1.

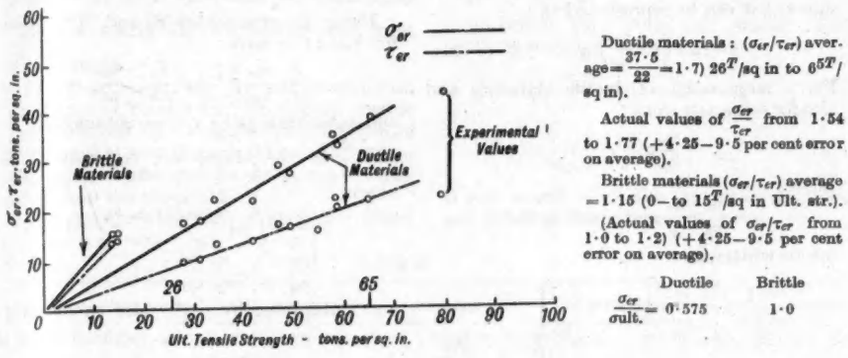


FIG. 1

Ductile materials : (σ_{er}/τ_{er}) average $=\frac{37{\cdot}5}{22}=1{\cdot}7)$ 26^T/sq in to 65^T/sq in).

Actual values of $\frac{\sigma_{er}}{\tau_{er}}$ from 1·54 to 1·77 (+4·25—9·5 per cent error on average).

Brittle materials (σ_{er}/τ_{er}) average $=1{\cdot}15$ (0—to 15^T/sq in Ult. str.).

(Actual values of σ_{er}/τ_{er} from 1·0 to 1·2) (+4·25—9·5 per cent error on average).

	Ductile	Brittle
$\frac{\sigma_{er}}{\sigma ult.}$ =	0·575	1·0

(3) *The* $\frac{k_{fT}}{k_{fB}}$ *Ratio.*—For sharp notches such as a vee notch this ratio varies between 0·6 to 1 for the various materials, while for milder notches such as oil holes and fillets the ratio is almost constant (0·76). For long keyways and splines this ratio may be as high as 2·0.(3) Thus, over the whole range investigated a variation of from 0·6 to 2·0 can be expected in normal machine design practice.

TABLE

Equation	Elastic failure criterion	Values of A_1	A_2	A_3
I	Maximum stress theory : $\sigma_{er}=\frac{\sigma}{2}+\sqrt{\frac{\sigma^2}{4}+\tau^2}$	0·5	0·25	1
II	Criterion for brittle materials : $\sigma_{er}=\frac{3}{8}\sigma+\frac{5}{8}\sqrt{\sigma^2+4\tau^2}$	0·375	0·39	1·562
III	Maximum shear theory : $\sigma_{er}=\sqrt{\sigma^2+4\tau^2}$	0	1	4
IV	Distortion energy theory : $\sigma_{er}=\sqrt{\sigma^2+3\tau^2}$	0	1	3

(4) *Values of* A_1, A_2 and A_3 are affected by the variation in the values for $R_1=\sigma_{er}/\tau_{er}$ and $R_2=k_{fT}/k_{fB}$. The expected variation in the values of these ratios are as follows :—

(1) *For Ductile Materials :*

$$R_1=\frac{\sigma_{er}}{\tau_{er}}=1{\cdot}54 \text{ to } 1{\cdot}77, \text{ and}$$

$$R_2=\frac{k_{fT}}{k_{fB}}=0{\cdot}6 \text{ to } 2{\cdot}0.$$

(2) *For Brittle Materials :*

$$R_1=\frac{\sigma_{er}}{\tau_{er}}=1 \text{ to } 1{\cdot}2.$$

$$R_2=\frac{k_{fT}}{k_{fB}}=0{\cdot}6 \text{ to } 2{\cdot}0.$$

It can be readily seen that equation (3) also expresses various elastic criteria of failure if suitable values for A_1, A_2 and A_3 are chosen. These values for the maximum stress, maximum shear, distortion energy and a recommended elastic criterion of failure for brittle materials are given in Table I :

In Table II values of $\frac{\sigma}{\sigma_{er}}$ for the ellipse arc criterion are listed, for the various combinations of $R_1=\frac{\sigma_{er}}{\tau_{er}}$ and $R_2=\frac{k_{fT}}{k_{fB}}$, as a function of the ratio τ/σ.

From Table II then the upper and lower limit of σ/σ_{er} for any one τ/σ ratio was determined separately for ductile (D) and for brittle materials (B), and these limiting values are again listed in Table III under D and B respectively.

The σ/σ_{er} values as a function of τ/σ ratio were then calculated for the I, II, III and IV elastic criteria and also listed in Table III :

In Fig. 2 curves for D, III and IV, and in Fig. 3, B, I and II are plotted. The cross-hatched area indicates the area within which the experimental results fall.

(5) Analysis of Figs. 2 and 3 reveals that for brittle materials the maximum stress theory is within the upper and lower limit,

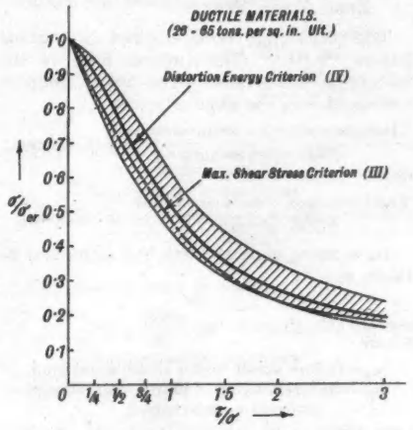


FIG. 2

while the modified criterion is nearer to the lower boundary. In view of the scarcity of data for brittle materials the latter criterion (II) is recommended as it is more conservative. For ductile materials the distortion energy criterion (IV) is well within the limits, while the maximum shear is near the lower boundary and is too conservative for large ratios of τ/σ. In view of the fact that

TABLE II—*Values of* σ/σ_{er} *for the Ellipse Arc Criterion*

$\tau/\sigma\rightarrow$		¼	½	1	2	3	
R_1	R_2						
1	0·6	0·78	0·662	0·572	0·368	0·27	Brittle materials (B)
	0·8	0·808	0·69	0·595	0·379	0·776	
	1·0	0·830	0·714	0·618	0·391	0·283	
	2·0	0·895 L	0·800 L	0·707 L	0·447 L	0·316 L	
1·1	0·6	0·765	0·643	0·550	0·346	0·251	
	0·8	0·792	0·67	0·573	0·358	0·258	
	1·0	0·815	0·695	0·595	0·368	0·263	
	2·0	0·885	0·785	0·690	0·424	0·296	
1·2	0·6	0·748 S	0·622 S	0·53 S	0·327 S	0·235 S	
	0·8	0·777	0·65	0·553	0·338	0·242	
	1·0	0·80	0·676	0·575	0·347	0·248	
	2·0	0·885	0·77	0·705	0·41	0·280	
1·54	0·6	0·696	0·561	0·466	0·281	0·193	
	0·8	0·73	0·592	0·49	0·289	0·198	
	1·0	0·757	0·618	0·573	0·299	0·204	
	2·0	0·847 L	0·72 L	0·610 L	0·350 L	0·231 L	
1·6	0·6	0·690	0·553	0·457	0·271	0·188	
	0·8	0·722	0·582	0·481	0·279	0·193	
	1·0	0·753	0·610	0·503	0·289	0·198	
	2·0	0·841	0·715	0·603	0·340	0·224	
1·7	0·6	0·676	0·538	0·442	0·255	0·178	Ductile materials (D)
	0·8	0·71	0·567	0·465	0·265	0·183	
	1·0	0·741	0·596	0·488	0·274	0·188	
	2·0	0·835	0·705	0·590	0·323	0·214	
1·77	0·6	0·665 S	0·528 S	0·432 S	0·246 S	0·172 S	
	0·8	0·668	0·556	0·455	0·256	0·177	
	1·0	0·73	0·581	0·476	0·264	0·181	
	2·0	0·826	0·69	0·580	0·314	0·206	

TABLE III—*Values of* σ/σ_{er} *as a Function of* τ/σ

τ/σ	Failure criterion							
	D		B		I	II	III	IV
	Lower (S)	Upper (L)	Lower (S)	Upper (L)				
0	1	1	1	1	1	1	1	1
¼	0·665	0·847	0·748	0·895	0·830	0·797	0·710	0·755
½	0·528	0·720	0·622	0·800	0·715	0·668	0·555	0·610
1	0·432	0·610	0·530	0·707	0·618	0·565	0·445	0·500
2	0·246	0·350	0·327	0·447	0·392	0·340	0·243	0·278
3	0·172	0·231	0·235	0·316	0·282	0·240	0·165	0·189

the data for ductile materials are quite reliable and cover a large range of materials, the less conservative and more economical distortion energy theory is recommended for completely reversed load.

In the following the effect of a non-zero mean stress will be investigated.

II. Failure of Parts Subjected to Simple Fluctuating Load with Non-Zero Mean Stress

This topic has been covered in various papers. [3], [4], [5] The simplest form of the maximum stress-mean stress relationship is a straight line, the slope of which is :

$$\frac{\text{Ultimate strength} - \text{endurance limit}}{\text{Ultimate strength}} \text{ (Goodman)}$$

or

$$\frac{\text{Yield strength} - \text{endurance limit}}{\text{Yield strength}} \text{ (Soderberg).}$$

In a more general form the slope can be taken as :

$$\frac{\sigma_p - \sigma_{er}}{\sigma_p},$$

where

σ_p = failure stress under static axial load.
σ_{er} = endurance limit under completely reversed normal stress,

and this can apply to both ductile and brittle materials. The maximum stress/mean stress diagram for any given life can then be constructed from the *SN* curve as shown in Fig. 4.

σ_m = mean stress.

The equation of this line can be written as :

$$\sigma = \sigma_{er} + \left(1 - \frac{\sigma_{er}}{\sigma_p}\right)\sigma_m,$$

or with

$$r = \frac{\sigma_{er}}{\sigma_p}$$

$$\sigma\left[1 - (1-r)\frac{\sigma_m}{\sigma}\right] = \sigma_{er}$$

$$\left.\begin{aligned} B \,.\, \sigma &= \sigma_{er}, \text{ where } B = 1 - (1-r)\frac{\sigma_m}{\sigma} \\ \text{or} \qquad \sigma &= \frac{\sigma_{er}}{B} \end{aligned}\right\} \quad . \quad (5)$$

Both σ and σ_m are actual stresses. Gough's experiments with some ductile steels reveal that in the presence of a notch only the alternating component of the stress at failure is reduced, but not the mean stress. Thus, when using ductile materials the strength reduction factor is only applied to the alternating part of the stress. However, when using brittle material, the strength reduction factor must be applied to both the mean and alternating part of the fluctuating stress.

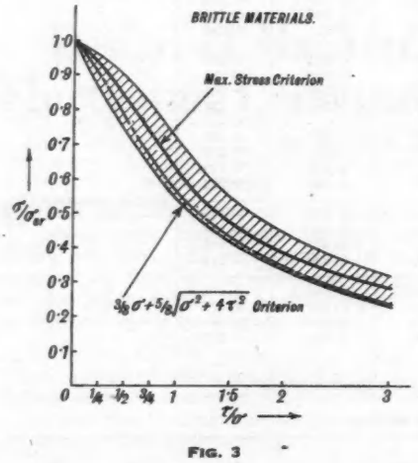


FIG. 3

Experiments under fluctuating torsion revealed that the range of fluctuation at failure is less affected by the mean stress in torsion than it is under bending or axial stress.[6] Thus a straight line similar to Fig. 4 used as maximum stress versus mean

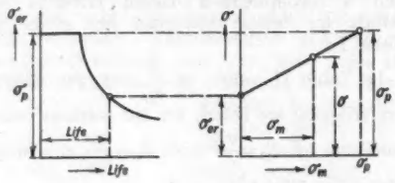


FIG. 4

stress relationship will be on the conservative side and it can be represented as :

$$\tau = \tau_{er} + \left(1 - \frac{\tau_{er}}{\tau_p}\right)\tau_m \quad . \quad . \quad . \quad (6a)$$

For a large range of ductile materials and also for some cast irons :

$$\frac{\tau_{er}}{\sigma_{er}} \simeq \frac{\tau_p}{\sigma_p}$$

Thus

$$r = \frac{\sigma_{er}}{\sigma_p} \simeq \frac{\tau_{er}}{\tau_p} \text{ and equation (6}a\text{)}$$

can be written as :

$$\left.\begin{aligned} \tau\left[1 - (1-r)\frac{\tau_m}{\tau}\right] &= \tau_{er} \\ T \,.\, \tau = \tau_{er}, \text{ where } T &= 1 - (1-r)\frac{\tau_m}{\tau} \\ \tau &= \frac{\tau_{er}}{T} \end{aligned}\right\} \quad . \quad . \quad (6)$$

For completely reversed stressing obviously $B = T = 1$, and thus the factors B and T express the effect of the mean stress on the maximum stress.

III. The Ellipse Arc Criterion of Failure for Combined Fluctuating Bending and Torsion with Non-Zero Mean Stress and Comparison of Experimental Results Obtained for a Ductile Steel, with a Suggested Elastic Criterion

The ellipse arc criterion of failure suggested by Gough can be written in the following form :—

$$\left(\frac{\tau_a}{t}\right)^2 + \left(\frac{\sigma_a}{b}\right)^2\left(\frac{b}{t} - 1\right) + \frac{\sigma_a}{b}\left(2 - \frac{b}{t}\right) = 1 \quad . \quad (7)$$

where τ_a, σ_a are the alternating components calculated from the load fluctuations, and t and b are torsional and bending endurance limits for the given mean stresses and notch.

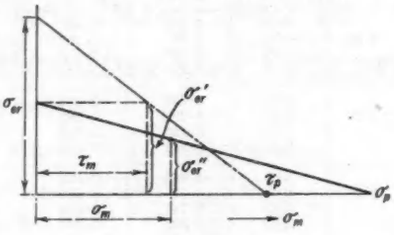


FIG. 5

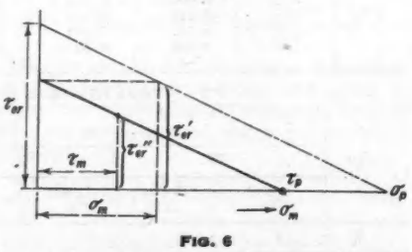


FIG. 6

This criterion can be transformed into a more convenient form if a certain law for reduction in τ_{er} and σ_{er} with the torsional and bending mean stresses is assumed.

Experimental evidence shows that the following simplified assumptions are well on the safe side (Figs. 5 and 6). For Fig. 5 :

$$\left.\begin{aligned} \sigma_{er}' &= \sigma_{er}\left(1 - \frac{\tau_m}{\tau_p}\right) \\ \sigma_{er}'' &= \sigma_{er}'\left(1 - \frac{\sigma_m}{\sigma_p}\right) = \sigma_{er}\left(1 - \frac{\tau_m}{\tau_p}\right)\left(1 - \frac{\sigma_m}{\sigma_p}\right) \\ b &= \frac{\sigma_{er}''}{k_{fB}} = \frac{\sigma_{er}}{k_{fB}}\left(1 - \frac{\tau_m}{\tau_p}\right)\left(1 - \frac{\sigma_m}{\sigma_p}\right) \end{aligned}\right\} \quad . \quad (8)$$

and for Fig. 6 :

$$\left.\begin{aligned} \tau_{er}' &= \tau_{er}\left(1 - \frac{\sigma_m}{\sigma_p}\right) \\ \tau_{er}'' &= \tau_{er}'\left(1 - \frac{\tau_m}{\tau_p}\right) = \tau_{er}\left(1 - \frac{\sigma_m}{\sigma_p}\right)\left(1 - \frac{\tau_m}{\tau_p}\right) \\ t &= \frac{\tau_{er}''}{k_{fT}} = \frac{\tau_{er}}{k_{fT}}\left(1 - \frac{\sigma_m}{\sigma_p}\right)\left(1 - \frac{\tau_m}{\tau_p}\right) \end{aligned}\right\} \quad . \quad (9)$$

Using the expressions (8) and (9) obtained for b and t we have :

$$\frac{b}{t} = \frac{\sigma_{er}}{\tau_{er}}\frac{k_{fT}}{k_{fB}} \text{ and } \frac{\sigma_{er}''}{\tau_{er}''} = \frac{\sigma_{er}}{\tau_{er}},$$

and substituting the values obtained for b, t and $\frac{b}{t}$ in the ellipse arc criterion (7) we obtain :

$$\left(\frac{k_{fT}\tau_a}{\tau_{er}''}\right)^2 + \left(\frac{k_{fB}\sigma_a}{\sigma_{er}''}\right)^2\left[\frac{\sigma_{er}}{\tau_{er}}\frac{k_{fT}}{k_{fB}} - 1\right] + \frac{k_{fB}\sigma_a}{\sigma_{er}''}\left[2 - \frac{\sigma_{er}}{\tau_{er}}\frac{k_{fT}}{k_{fB}}\right] = 1,$$

and multiplying by $(\sigma_{er}'')^2$, also substituting :

$k_{fT}\tau_a$ = actual alternating torsional stress at failure = $\tau - \tau_m$
$k_{fB}\sigma_a$ = actual alternating bending stress at failure = $\sigma - \sigma_m$,

where σ, τ are actual maximum stresses at failure and σ_m, τ_m are the actual mean stresses at failure, we obtain :

$$\left(\frac{\sigma_{er}}{\tau_{er}}\right)^2\tau^2\left(1 - \frac{\tau_m}{\tau}\right)^2 + \sigma^2\left(1 - \frac{\sigma_m}{\sigma}\right)^2\left[\frac{\sigma_{er}}{\tau_{er}}\frac{k_{fT}}{k_{fB}} - 1\right] + \sigma\left(1 - \frac{\sigma_m}{\sigma}\right)\sigma_{er}''\left[2 - \frac{\sigma_{er}}{\tau_{er}}\frac{k_{fT}}{k_{fB}}\right] = (\sigma_{er}'')^2 \quad . \quad (7a)$$

It can be seen that above equation takes the form of :

$$A_1\sigma\left(1 - \frac{\sigma_m}{\sigma}\right) + \sqrt{A_2\sigma^2\left(1 - \frac{\sigma_m}{\sigma}\right)^2 + A_3\tau^2\left(1 - \frac{\tau_m}{\tau}\right)^2} = \sigma_{er}'',$$

or

$$A_1B'\sigma + \sqrt{A_2(B'\sigma)^2 + A_3(T'\tau)^2} = \sigma_{er} \quad . \quad (10)$$

where A_1, A_2, A_3 are the same as given by equations (4) and

$$\left.\begin{aligned} B' &= \frac{1 - \frac{\sigma_m}{\sigma}}{\left(1 - \frac{\tau_m}{\tau_p}\right)\left(1 - \frac{\sigma_m}{\sigma_p}\right)} \\ T' &= \frac{1 - \frac{\tau_m}{\tau}}{\left(1 - \frac{\tau_m}{\tau_p}\right)\left(1 - \frac{\sigma_m}{\sigma_p}\right)} \end{aligned}\right\} \quad . \quad . \quad . \quad (11)$$

are factors which express the influence of the mean stress. For $\tau_m = \sigma_m = 0$, $B' = T' = 1$, and therefore equation (10) for this case is identical with equation (3).

Thus, it is logical that the elastic criteria (II and IV, Table I) already suggested shall be proposed for non-zero mean stress, the difference being only that $B'\sigma$ is used in lieu of σ and $T'\tau$ in lieu of τ.

The only disadvantage of using factors B' and T' is that the ratios $\frac{\tau_m}{\tau_p}$ and $\frac{\sigma_m}{\sigma_p}$ cannot be predetermined from the load fluctuations. This is a serious disadvantage in design and it is suggested, therefore, that in lieu of B' and T' the factors $B = 1 - (1-r)\frac{\sigma_m}{\sigma}$ and $T = 1 - (1-r)\frac{\tau_m}{\tau}$ be used. These factors can be calculated from the material properties and load fluctuations; also equa-

tions similar to equations (5) and (6) will be obtained for $\tau=0$ and $\sigma=0$ respectively.

Thus for ductile materials the simplified ellipse are criterion with $A_1=0$, $A_2=1$ and $A_3=3$ will become :

$$\sqrt{(B'\sigma)^2+3(T'\tau)^2}=\sigma_{er} \quad . \quad . \quad . \quad . \quad (12)$$

while if B and T are used in lieu of B' and T',

$$\sqrt{(B\,.\,\sigma)^2+3(T\tau)^2}=\sigma_{er} \text{ is obtained} \quad . \quad (13)$$

for $\tau=0$ this reduces to

$$B\,.\,\sigma=\sigma_{er},$$

and for $\sigma=0$ to :

$$T\,.\,\tau=\frac{\sigma_{er}}{\sqrt{3}}=\frac{\sigma_{er}}{1\cdot73}\simeq\tau_{er},$$

which is in good agreement with the ratio $\frac{\sigma_{er}}{\tau_{er}}=1\cdot7$, found by experiment for most ductile steels.

It will be shown now by comparison with experimental results for one typical ductile steel obtained by Gough[3] that the use of equation (13) is on the safe side, and is reasonably rational and that its use is more economical than the use of (12).

The ductile steel B.S. S 65 A, for which experimental data for combined fluctuating bending and torsion in phase with non-zero mean stress are available, is a 65-ton nickel-chromium-molybdenum-vanadium steel with the following mechanical properties :—

Ultimate strength = 65 tons per square inch
σ_p = yield strength = 61 tons per square inch
$\sigma_{er}=\pm38$ tons per square inch.
$\tau_{er}=\pm24$ tons per square inch.

τ_p = yield strength in torsion = 46 tons per square inch. The ratio σ/σ_{er} was calculated from the actual experimental results for combinations of τ_m and σ_m and for varying τ/σ ratios. As a comparison equations (12) and (13) were written in the form of :

$$\frac{\sigma}{\sigma_{er}}=\frac{1}{\sqrt{(B')^2+3(T'\tau)^2}} \quad . \quad . \quad (12a)$$

and

$$\frac{\sigma}{\sigma_{er}}=\frac{1}{\sqrt{(B)^2+3(T\,.\,\tau)^2}} \quad . \quad . \quad (13a)$$

The results are tabulated in Table IV, giving also the actual values of τ_m, σ_m, τ and σ :

These results show that for $\tau_m=\sigma_m=0$ the agreement is very good and that the error on the safe side by using equation (13) increases with increasing mean stress. However, it can be said that for this particular steel equation (13) is a rational design equation not too conservative. It is also clear that equation (13) for completely reversed stresses reduces to equation IV (Table I), which agrees very well with experimental results on most ductile steels and that it reduces to equations (5) and (6) for fluctuating bending only or fluctuating torsion only.

TABLE IV

Tons per square inch					σ/σ_{er}			Percentage difference between Equation (13) and actual	Average percentage error on safe side
τ/σ	τ_m	σ_m	τ	σ	Actual	Equation (13)	Equation (12)		
0			0	38	1	1	1	0	
0·286	0	0	10	35	0·92	0·90	0·90	2·2	2·5
0·666			16·5	25	0·66	0·638	0·638	3	
2			21	10·6	0·278	0·278	0·278	0	
0·310	11	0	11	35·6	0·938	0·886	0·761	8·5	20
1·100			27·7	25	0·66	0·47	0·500	30	
0	0	17½	0	53	1·39	1·02	1·07	27	26
0·155			16·7	42·3	1·11	0·84	0·80	25	
0·206			11	53·3	1·40	0·970	0·805	31	
0·41	11	17½	20	48	1·26	0·835	0·762	33	35
0·66			27	41	1·08	0·675	0·612	38	
1·14			32	28	0·735	0·465	0·405	37	
0·343			22·3	65	1·71	0·895	0·476	47	
0·490	22½	34½	30	61	1·6	0·79	0·465	50	50
0·640			36	56	1·47	0·695	0·400	52	
0·910			39	43	1·13	0·565	0·325	50	

IV. Suggested Procedure for the Design of Machine Parts Subjected to Combined Fluctuating Bending and Torsion

On the basis of the survey carried out in Sections I, II and III, it is suggested that the following equations be used for the design of parts subjected to combined bending and torsion :—

(*a*) Ductile steels :

$$\sqrt{(B\sigma)^2+3(T\tau)^2}=\sigma_{er}, \text{ or using } r=\frac{\sigma_{er}}{\sigma_p}$$

$$\sqrt{\left(\frac{B}{r}\sigma\right)^2+3\left(\frac{T}{r}\tau\right)^2}=\sigma_p \quad . \quad . \quad . \quad . \quad . \quad (14)$$

(*b*) Brittle cast irons and similar other brittle materials :

$$\frac{3}{8}B\sigma+\frac{5}{8}\sqrt{(B\sigma)^2+4(T\,.\,\tau)^2}=\sigma_{er}$$

or

$$\frac{3}{8}\left(\frac{B}{r}\sigma\right)+\frac{5}{8}\sqrt{\left(\frac{B}{r}\sigma\right)^2+4\left(\frac{T}{r}\tau\right)^2}=\sigma_p \quad . \quad . \quad (15)$$

Where τ and σ are the maximum torsional and bending stresses and

$$B=1-(1-r)\frac{\sigma_m}{\sigma}$$

$$T=1-(1-r)\frac{\tau_m}{\tau},$$

σ_m and τ_m being the mean stresses.

For parts made of ductile materials only the alternating part is affected by the stress raiser and thus (with strength reduction factors k_{fB} and k_{fT}),

$$\sigma_m=\frac{\phi_B\,.\,M_{Bm}}{Z_B} \qquad \tau_m=\frac{\phi_T\,.\,M_{Tm}}{Z_T}$$

$$\sigma=\frac{\phi_B}{Z_B}[M_{Bm}+k_{fB}(M_B-M_{Bm})],$$

and

$$\tau=\frac{\phi_T}{Z_T}[M_{Tm}+k_{fT}(M_T-M_{Tm})].$$

Where Z_B, Z_T are the sectional moduli in bending and torsion respectively, and M_{Bm}, M_B and M_{Tm}, M_T are the mean and maximum values of the bending and torsional moments. ϕ_B and ϕ_T are marginal factors for bending and torsion.

The actual maximum bending and torsional stresses at failure can be then written as :

$$\sigma=\frac{\phi_B M_B}{Z_B}\left[k_{fB}-\frac{M_{Bm}}{M_B}(k_{fB}-1)\right]$$

$$=K_{NB}\frac{\phi_B M_B}{Z_B}=K_{NB}\sigma_c$$

$$\tau=\frac{\phi_T M_T}{Z_T}\left[k_{fT}-\frac{M_{Tm}}{M_T}(k_{fT}-1)\right]$$

$$=K_{NT}\frac{\phi_T M_T}{Z_T}=K_{NT}\tau_c,$$

where τ_c and σ_c are the calculated maximum torsional and bending stresses respectively.

For parts made of brittle materials :—

$$\sigma_m=\frac{\phi_B k_{fB} M_{Bm}}{Z_B} \qquad \tau_m=\frac{\phi_T k_{fT} M_{Tm}}{Z_T}$$

$$\sigma=\frac{\phi_B k_{fB} M_B}{Z_B} \qquad \tau=\frac{\phi_T k_{fT} M_T}{Z_T}.$$

Thus we can write in general for both ductile and brittle materials :

$$\sigma_m=\frac{\phi_B K_{SB} M_{Bm}}{Z_B} \qquad \tau_m=\frac{\phi_T K_{ST} M_{Tm}}{Z_T}$$

$$\sigma=\frac{\phi_B K_{NB} M_B}{Z_B} \qquad \tau=\frac{\phi_T K_{NT} M_T}{Z_T},$$

where

K_{SB} = mean stress factor in bending
$= \begin{cases} 1 \text{ for ductile materials} \\ k_{fB} \text{ for brittle materials} \end{cases}$

K_{ST} = mean stress factor in torsion
$= \begin{cases} 1 \text{ for ductile materials} \\ k_{fT} \text{ for brittle materials} \end{cases}$

K_{NB} = notch factor in bending
$= \begin{cases} k_{fB}-\dfrac{M_{Bm}}{M_B}(k_{fB}-1) \text{ for ductile materials} \\ k_{fB} \text{ for brittle materials} \end{cases}$

K_{NT} = notch factor in torsion
$= \begin{cases} k_{fT}-\dfrac{M_{Tm}}{M_T}(k_{fT}-1) \text{ for ductile materials} \\ k_{fT} \text{ for brittle materials} \end{cases}$

. . . . . (16)

Thus :

$$\frac{\sigma_m}{\sigma}=\frac{K_{SB}M_{Bm}}{K_{NB}M_B} \text{ and } \frac{\tau_m}{\tau}=\frac{K_{ST}M_{Tm}}{K_{NT}M_T}$$

$$\frac{B}{r}\sigma=\frac{\phi_B K_{NB} M_B}{Z_B}\frac{1}{r}\left[1-(1-r)\frac{K_{SB}M_{Bm}}{K_{NB}M_B}\right]$$

$$=\frac{\phi_B K_B M_B}{Z_B}$$

$$\frac{T}{r}\tau=\frac{\phi_T K_{NT} M_T}{Z_T}\frac{1}{r}\left[1-(1-r)\frac{K_{ST}M_{Tm}}{K_{NT}M_T}\right]$$

$$=\frac{\phi_T K_T M_T}{Z_T}.$$

The fatigue load factors in bending and torsion are K_B and K_T respectively :

$$\left.\begin{aligned} K_B&=\frac{K_{NB}}{r}\left[1-(1-r)\frac{K_{SB}M_{Bm}}{K_{NB}M_B}\right] \\ K_T&=\frac{K_{NT}}{r}\left[1-(1-r)\frac{K_{ST}M_{Tm}}{K_{NT}M_T}\right] \end{aligned}\right\} \quad . \quad (17)$$

and they can be calculated if r, k_{fB}, k_{fT} and the load fluctuations are known.

Equations (14) and (15) can then be rewritten as :

$$\sqrt{\left(\frac{\phi_B K_B M_B}{Z_B}\right)^2+3\left(\frac{\phi_T K_T M_T}{Z_T}\right)^2}=\sigma_p \quad . \quad (14a)$$

$$\frac{3}{8}\frac{\phi_B K_B M_B}{Z_B}+\frac{5}{8}\sqrt{\left(\frac{\phi_B K_B M_B}{Z_B}\right)^2+4\left(\frac{\phi_T K_T M_T}{Z_T}\right)^2}$$

$$=\sigma_p \quad . \quad . \quad . \quad . \quad . \quad (15a)$$

and they are of the same form as those used under static load (such as equation (1)).

Thus :

(*a*) For completely reversed bending and torsion :

$M_{Bm}=M_{Tm}=0$, and thus

$$K_B=\frac{k_{fB}}{r} \qquad K_T=\frac{k_{fT}}{r}.$$

(*b*) For static load or where the fluctuations are negligibly small :

$$M_{Bm}\simeq M_B \qquad M_{Tm}\simeq M_T$$

$$K_{NB}=\begin{cases}1 \text{ ductile} \\ \text{or} \\ k_{fB} \text{ brittle}\end{cases} \qquad K_{NT}=\begin{cases}1 \\ \text{or} \\ k_{fT}\end{cases}$$

$$K_B=\begin{cases}1 \\ \text{or} \\ k_{fB}\end{cases} \qquad K_T=\begin{cases}1 \\ \text{or} \\ k_{fT}\end{cases}$$

and equations (14*a*) and (15*a*) reduce to those used for static load.

(*c*) Fluctuating bending only (from equations (14*a*) and (15*a*)):

$$\frac{\phi_B K_B M_B}{Z_B}=\sigma_p.$$

(*d*) Fluctuating torsion only:

$$\frac{\phi_T K_T M_T}{Z_T}=\frac{\sigma_p}{\sqrt{3}} \quad . \quad . \quad . \quad (14b)$$

$$\frac{\phi_T K_T M_T}{Z_T}=0{\cdot}8\sigma_p \quad . \quad . \quad . \quad (15b)$$

Example of Design.—Calculate the diameter of a rotating shaft made of the following material:—

3½ per cent Ni-Cr steel (normal impact).
$\sigma_{cr}=\pm 33{\cdot}6$ tons per square inch.
σ_p=Upper yield point=49·2 tons per square inch.
$\phi_B=\phi_T=1{\cdot}5$ loaded as shown in Fig. 7.

A, *D* are bearings.

$$\frac{T_{C1}}{T_{C2}}=\frac{T_{B1}}{T_{B2}}=6.$$

Torque supplied at *C* used at *B* fluctuates from 1·5 ton-inches to 10 ton-inches, the

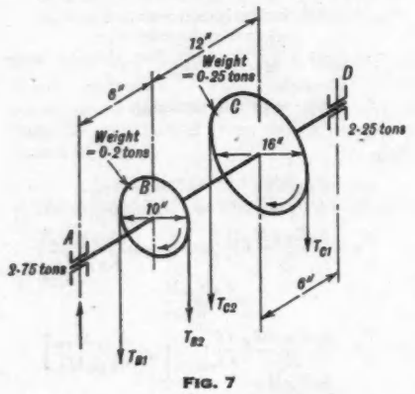


FIG. 7

frequency of fluctuations being slower than the rotation. Thus calculated from the maximum torque:

$T_{C2}=0{\cdot}25$ ton $\quad T_{C1}=1{\cdot}5$ ton
$T_{B2}=0{\cdot}4$ $\quad T_{B1}=2{\cdot}4$ ton

and the maximum transverse forces on the shaft are:

$P_B=3$ ton $\quad P_C=2$ ton.

The maximum bending moment is at *B*:

$$M_B=16{\cdot}5 \text{ ton-inches},$$

and the bending stress is completely reversed.

A keyway is assumed at *B* and *C* which will result in strength reduction factors $k_{fT}=1{\cdot}6$ and $k_{fB}=1{\cdot}2$ for the given material and keyway proportions.

The fatigue load factors can be now calculated as follows:—

$$r=\frac{\sigma_{cr}}{\sigma_p}=\frac{33{\cdot}6}{49{\cdot}2}=0{\cdot}684.$$

$$M_{Tm}=\frac{1}{2}(10+1{\cdot}5)=5{\cdot}75 \text{ ton-inches}$$

$$M_T=10 \text{ ton-inches}$$

$$K_{ST}=1,\ K_{NT}=k_{fT}-\frac{M_{Tm}}{M_T}(k_{fT}-1)$$

$$=1{\cdot}6-\frac{5{\cdot}75}{10}\cdot 0{\cdot}6=1{\cdot}255.$$

$$K_T=\frac{K_{NT}}{r}\left[1-(1-r)\frac{M_{Tm}}{1{\cdot}255M_T}\right]$$

$$=\frac{1{\cdot}253}{0{\cdot}684}\left[1-(1-0{\cdot}684)\frac{5{\cdot}75}{1{\cdot}255\times 10}\right]=1{\cdot}57$$

$$K_B=\frac{k_{fB}}{r}=\frac{1{\cdot}2}{0{\cdot}684}=1{\cdot}75.$$

For a circular section the diameter at *B* can be calculated from equation (14*a*) as:

$$\phi_B\frac{32}{\pi d_B^3}\sqrt{(K_BM_B)^2+\frac{3}{4}(K_TM_T)^2}=\sigma_p$$

$$d_B=\sqrt[3]{\frac{32\times\phi_B}{\pi\cdot\sigma_p}\sqrt{(K_BM_B)^2+\frac{3}{4}(K_TM_T)^2}}$$

$$=\sqrt[3]{\frac{32\times 1{\cdot}5}{\pi\cdot 49{\cdot}2}\sqrt{(1{\cdot}75\times 16{\cdot}5)^2+\frac{3}{4}(1{\cdot}57\times 10)^2}}$$

$$=\sqrt[3]{\frac{32\times 32\times 1{\cdot}5}{\pi\times 49{\cdot}2}}=2{\cdot}15\text{in.}$$

Conclusion.—It was shown that design equations similar in form to those used in design for static load can be utilised for the design of parts subjected to fluctuating combined bending and torsion. In these formulæ the maximum bending moment and torsional moment are multiplied by fatigue load factors which can be precalculated from the load fluctuations, material properties and strength reduction factors. The formulæ are simple in form, easy to use and in reasonable agreement with existing experimental data.

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The British Contribution to Science and Technology in the Past Hundred Years*

By H.R.H. THE DUKE OF EDINBURGH, K.G., F.R.S.

The Starting Point

IN a review of British science and technology, 1851 is a convenient starting point for two reasons. First, the exhibition of that year can be regarded as a gigantic stocktaking of the national resources and technical skill. Secondly, because it marked the end of the Industrial Revolution and the conversion of Victorian England to the policy of industrial expansion on which our future still depends. The period as a whole saw the climax of our industrial supremacy and its inevitable decline when countries with greater resources and population learned from us the lessons of the mechanisation of industry. It also covers the birth and growth of the new concepts of modern science.

Social conditions of a hundred years ago were, generally speaking, the outcome of the Industrial Revolution, but with all the traditions of the England of agriculture, cottage industry and small market towns. The population of 20 millions was growing fast, but still small compared with our 50 millions of to-day. Education was limited to a minority and was almost entirely classical, so the new profession of engineering had to draw its recruits from a different sphere, that of self-educated men. A new wealthy class was growing up in the commercial world to rival the old aristocracy. There was unbounded optimism about the future, and ample scope in commerce and industry to attract all intelligent and enterprising men. The number of poor was on the increase and their conditions were deteriorating because, as yet, no social conscience had grown up to replace the patriarchal responsibility of the landowners and master craftsmen.

In the domestic field, lighting was by candle and oil lamps, cooking and heating by coal or wood in ranges or open fires, with the consequent enormous waste of energy. Food had to be fresh or crudely preserved, and thus needed to be produced locally. In health and hygiene the figures speak for themselves. In 1851 the infant deathrate was 150 per 1000 living births, compared with 25 per 1000 to-day. Anæsthetics, antiseptic surgery, biochemistry, tropical medicine, were all virtually unknown or in their infancy. Psychology had not yet achieved independence from philosophy, on the one hand, and physiology, on the other.

This was the age of the practical engineer and of processes arrived at by intuition born of experience and by trial and error. Technology was concerned with the application of steam power, with metallurgy and the working of metals for various purposes, and with the production of machine tools and precision machinery. Men were already turning their minds to other types of engines and the internal combustion engine was in the process of development.

Scientists, while continuing their search for the secrets of Nature, were beginning to turn their attention to exploring the empirical developments of industry. Their numbers as yet were small, the endowments for research were negligible and much of their work was carried out in the watertight compartments of the different sciences. But the seed had been sown, and it was not long before scientists and engineers were preparing the way for the great technological harvest of the twentieth century.

The Conditions

The changes brought about in the lives of men and women in the last hundred years have been greater and more rapid than during any other period in history, and these changes have been almost entirely due to the work of scientists and technologists all over the world. They have not only affected the way of living of all civilised peoples but have also vastly increased our knowledge about ourselves, the earth we live on and the universe around us. I cannot emphasise too much that the sum total of scientific knowledge and technological progress is an international achievement to which every civilised country has made some contribution.

And now before considering the contribution of the British Commonwealth, I should like to sketch what appear to a layman like myself to have been the main influences on the course of scientific and technical achievement since 1851, and their relation to one another.

The great stimulus of the 1851 Exhibition created a growing interest in technical education and research, followed by a widening of the scientific horizon which was soon to find expression in borderline subjects. For the next fifty years science advanced rapidly, but in most fields there was a wide gap between science and in-

* Presidential Address to the British Association, Edinburgh, August 8th. Abstract.

dustry. Electricity was an exception and the groundwork was already being laid for the electrical revolution of the Victorian age. Medicine was on the verge of breaking away from mediæval practice and taking the first steps towards its modern pattern, while British colonial development stimulated the study of tropical disease.

Between 1851 and 1870 practice, in many industries, was ahead of science, and in that period the large number of inventions of the Industrial Revolution were progressively improved and widely applied. These inventions, which added so much to our industrial production, were mainly the work of British genius. They were of great economic advantage to this country and were quickly exploited commercially. New factories and plants were built to include the very latest ideas, and with the expansion of industry came the demand for more and more new ideas and greater efficiency. This demand was a direct stimulus to technological invention as well as an indirect stimulus to science. We are still struggling with the social results of this vast expansion.

From 1870 to 1890 the high-water mark of British industrial expansion, as compared with other countries, had been reached and the competition of the United States and Europe was just beginning to be felt. But the lack of serious competition hitherto had bred a feeling of over-confidence and satisfaction in the methods and processes employed. The result was a conservative attitude towards technical change and, particularly in the older industries, neglect of scientific research. Accumulation of wealth and the income from foreign investments in any case made the country as a whole less dependent on the efficiency of her industries. Concurrently a subtle change occurred in the type of British exports. So far the products of our machinery, such as rails and rolling stock, had been shipped abroad for immediate use, but now machines themselves were exported to do their work in the factories of Europe and America instead of in Britain. The result of this was to intensify foreign industrial competition between 1890 and 1914, but with the increasing demands from the Colonies the volume of British exports was not greatly affected.

Then came the critical years of the First World War, bringing a realisation of the part science must play in the industrial and military strength of the nation. For the first time in history a real attempt was made to enlist the services of science in the war effort, and the Department of Scientific and Industrial Research was founded to further the application of science in industry through Government Laboratories and Research Associations.

The effects of these measures appeared clearly in the inter-war years, when there was a marked swing of education from classics towards science. Coupled with this, the war had directed the attention of many research scientists to practical objectives, so that after the war there was a rapid expansion of industrial research. Scientific progress was no longer confined to the work of a few brilliant individuals, but came also from teams of research scientists, each working on different parts of the same problem. It was during this period that many new commercial research laboratories grew up, employing scientists to discover new processes and materials connected with their industry as a direct weapon of competition.

The war had also shown a great weakness in our dependence on foreign production for many vital articles, such as dyestuffs, scientific instruments and optical glass, in the manufacture of which scientific research played an essential part. This weakness was remedied with the help of the key industry import duties, which gave the necessary support and encouragement to the establishment of these industries at home.

It is true that manufacturers in some of the older industries still clung to traditional methods in spite of the pressure of competition from America and other countries. And in this connection it is significant that the history of production engineering after 1890 is almost entirely confined to the United States.

It was, however, a period of rapid development in Britain. The invention of the internal combustion engine and the pneumatic tyre had opened new branches of industrial engineering, and the demand for fuel for motor-cars and aircraft gave birth to the new technology of oil. In the electrical, chemical and aircraft industries, science was fully enlisted in the fields of electronics, synthetic fibres, plastics, aerodynamics, and light alloys. Consequently the outbreak of war in 1939 found us in a much stronger position to meet the immense demands it made on all branches of technology for new gadgets, machines and weapons. From the outset science in all its forms and branches was harnessed and completely co-ordinated with the war effort. It was only the intimate partnership of science and engineering with the staffs of the Fighting Services that enabled us to meet swiftly and effectively the ever-changing menace of total war.

The tremendous demands on our industries had some good after-effects. Once again these demands revealed weaknesses where our industrial capacity was out of date. The realisation of this has initiated comprehensive reconstruction on most modern lines. The almost complete absence of income from our foreign investments has forced us to rely once more on our capacity to make the goods the world requires. Our industry and productivity have shown a wonderful improvement, but there is still a lot more that can be done. The rate at which scientific knowledge is being applied in many industries is too small and too slow. Our physical resources have dwindled, but the intellectual capacity of our scientists and engineers is as great as ever and it is upon their ingenuity that our future prosperity largely depends.

The Implications

The story of the British contribution to science in the past century is indeed impressive, and I am very pleased to have this opportunity to pay tribute to the men whose achievements I have been discussing. But this story would not be complete without studying the wider implications of their work and examining some of the lessons to be learnt from it.

The concrete measurement and indirect effect of all scientific effort is the general improvement in the condition in which people live and work, it is in the improvement in health, in the expectation of life and standards of living. The latter, includes not only food and clothing, but housing, home comforts, medical care, education, books and newspapers, recreations and travel facilities. In every one of these directions the progress that has been made has amounted to a revolution.

Not all this springs directly from science and invention. Much has been due to the politicians and administrators, and behind them to religion, morals, education, art and the complex influences which we call culture. But even there science has stood beside the authors of progress to advise, to help and sometimes to guide.

Now as science and technology are so vital to the future strength and prosperity of the British Commonwealth, the great problem is to discover the conditions under which they are most likely to flourish. The records show that both depend very much on co-operation, and upon the linking up of a long chain of discoveries, one with another; so that it is quite exceptional for the credit of a great advance to belong to one man or even to one country, although it will always require the flash of inspiration to weld the links into the chain. To-day the development of teamwork in laboratories has made this truer than ever. For many reasons, but principally because of the increasing complexity of research and its cost, such teamwork is becoming more and more the rule. We need not repine at this, but it would be a disaster if the individual inquirer working in his own laboratory were discouraged out of existence.

While the quality of scientific work is determined by the quality of the scientist, the quantity of scientific output is determined by the money available. The rapid progress of science in Britain has owed much to the growing support and sympathy of government and individual benefactors and to the endowment of research by industrial corporations. However, the basic discoveries that mark the great advances depend on the accident of individual genius and are not at our command.

The scope and intensity of the progress of applied science and technology, on the other hand, bear a close relationship to the circumstances of the time. Technology, as the combination of scientific knowledge with the practical ability of the inventor to apply that knowledge to the solution of particular problems, comes into play with any new discovery of scientific fact. The latest particle of truth is then developed, according to the circumstances of the time for military, commercial or medico-social purposes. It is a sad reflection that the urgent demands of modern war can produce advances that might otherwise take many years to develop, especially in the costly and uncertain experimental stages.

The rivalry between large commercial undertakings, using science to improve their products or processes as a direct means of competition, has produced a steady flow of improvements and developments. However, the fruits of this form of scientific work are sometimes open to considerable misuse. The discoveries of these commercial laboratories may be kept secret and in some cases a number of teams may be working on the same problem, which may have already been solved elsewhere. The buying up and suppression of patents and discoveries to protect equipment from becoming obsolete has also been known to happen. I am glad to see, however, a change of outlook in the growing quantity of publication of the results of industrial research.

It would seem that science has become so well established that nothing can stand in the way of its natural growth. This is far from the truth. Since the earliest times the natural conservatism of laymen has acted as a powerful brake to the adoption of new ideas, which do not rigidly conform to his notion of the correct order of things. In its most violent form it will produce unreasoning anger, utter disbelief in face of the clearest evidence or provoke plain, ordinary laughter. The storm raised by Darwin's "Origin of Species" is an excellent example, where even scientists failed to keep an open mind.

The position seems better to-day and I

am sure that Sir Harold Hartley, our immediate past president, spoke for all scientists when he said :—

"To-day, with our greater understanding, there is humility in the minds of all scientists. The further we penetrate into Nature's secrets the more clearly we see the ever-receding frontiers of knowledge."

The resistance towards anything new or unexpected is balanced, on the other hand, by bursts of enthusiasm that some particular discovery or invention will see the end of all our troubles. The belief in the philosopher's stone seems to be just as great as ever.

As the front of pure science has advanced so its lines of communication to practical exploitation have got longer and longer. The time was when the whole process of discovery, application and exploitation could be achieved by one man. In our time a great army of scientists, technicians, inventors, designers and production engineers are required to keep the lines of communication open. Quite how important some of the members of this follow-up team have become is not always appreciated. In his presidential address in 1948 Sir Henry Tizard emphasised this point when he said :—

"All depends on good design and production. Our weakness in the war was not to be found in what was best to do, nor in the scientific work of how to do it. It was when the stage of design and production was reached that we fell short of the best standards."

This was true already when Whitworth invented the screw micrometer, which was subsequently put into production in Germany and the United States and up to the 1914 war all micrometers had to be imported into this country.

To Professor Kipping, of Nottingham, goes the credit for the basic work which led to the development of silicones in Russia and the United States and yet until this year we have been dependent on imports from America of marketable silicone products.

There are many cases in the Navy where a piece of apparatus has been used operationally exactly as the inventor put it together, with all the resulting disadvantages in maintenance and efficient operation. The limitation in performance, except in some cases, is practical as opposed to scientific. Where the basic scientific principles are known by all nations the advantage lies in the good design of equipment for practical use.

A more general and far-reaching matter for concern and possibly the most vital factor affecting the industrial application of scientific research is the lack of a co-ordinated system of scientific and technological education in this country. Excellent as they are, the existing institutions, which have grown up to meet particular circumstances, do not produce anything like enough trained technologists to meet the urgent needs of scientific development in industry and to provide leaders for the future. It is to be hoped that the new and rather uncertain science of education will develop sufficiently quickly to point the way to a speedy solution of this problem.

The shortage in Britain of "personnel trained and eager to apply scientific knowledge and scientific methods to practical ends"—as Sir Ewart Smith said last year—is only one of the many shortages which the world is now facing. Among them are food, non-ferrous metals, steel alloy metals and sulphur. These very shortages are due to the scientific complexity of present-day life and it is only by science that they can be overcome. Naturally there are many ways of tackling this problem; but the most obvious are first by improved design to secure economy in production and the minimum use of scarce materials. Secondly, by the development of substitutes made from raw materials which are still abundant. Thirdly, by the reclamation of scrap and improved methods of using low-grade ores. Finally, the development of renewable raw materials, such as timber, to satisfy the world demand for cellulose. Some of these shortages are partly due to the huge, inevitable waste of war and its consequences, and partly to the lack of any comprehensive survey of the world's resources and requirements. It is only by an accurate knowledge of the world's resources that we can foresee the scope and magnitude of the future problems that science and technology have to meet and that only they can solve.

It is, therefore, good news that the Economic and Social Council of the United Nations has resolved "to promote the systematic survey and inventory" of those resources which are not already covered by the Food and Agriculture Organisation.

We have evolved a civilisation based on the material benefits which science and technology can provide. The present shortages are a timely reminder of the slender material foundation on which our civilisation rests and of our dependence upon science and technology.

The Conclusion

The pursuit of truth in itself cannot produce anything evil. It is in the later stage, when the facts dug up enter the process of application that the choice between the beneficent and destructive development has to be made. It is quite certain that it is an exception if any particular discovery cannot be used equally well for good and evil purposes. Happily, the beneficent exploitation of scientific knowledge has kept pace with its destructive application.

In a mid-century article *The Times* put it this way: "... It has been an age of great achievement. The lines of progress in which the Victorians trusted have been pursued farther and faster than they foresaw. Scientific discovery, from which above all their doctrines of progress derived, has swept forward on an enormous front. The conquest of the air has made possible an intercourse and understanding between distant peoples, such as our ancestors could not imagine—and it has been diverted to the vast destruction of men and cities. The invention of wireless telephony has opened a channel through which liberating truths might be proclaimed to all the listening earth—and every would-be despot has used it to suborn the blind masses into the worship of false gods. The medical art has performed miracles; the cures of immemorial pestilences have been found, infancy has been safeguarded and old age tended, so that the normal expectation of life has been extended by years—aside from the new and universal apprehension of sudden death."

To my mind it is vital that the two sides of scientific development are fully and clearly understood, not only by the research scientist, inventor, designer and the whole scientific team, but also by all laymen. The instrument of scientific knowledge in our hands is growing more powerful every day, indeed, it has reached a point when we can either set the world free from drudgery, fear, hunger and pestilence or obliterate life itself.

Progress in almost every form of human activity depends upon the continued efforts of scientists. The nation's wealth and prosperity are governed by the rapid application of science to its industries and commerce. The nation's workers depend upon science for the maintenance and improvement in their standard of health, housing and food. Finally, superiority or even our ability to survive in war is a direct measure of the excellence and capacity of the scientific team.

This team of research workers and engineers has a dual responsibility, one for its work and the other as informed citizens, and it can only fulfil its proper functions if its members have a sound general education as well as a thorough training in science. It is no less important that the people who control the scientific machine, both laymen and scientists, should have a proper understanding and appreciation of what science has grown into and its place among the great forces of the world.

Ladies and gentlemen, it is clearly our duty as citizens to see that science is used for the benefit of mankind. For, of what use is science if man does not survive?

The Conservatoire National des Arts et Metiers

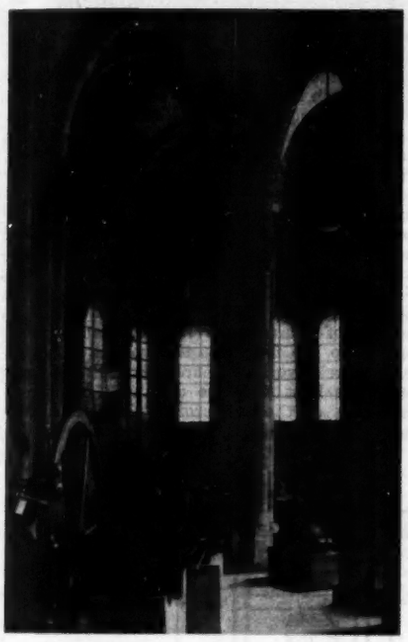
(*Contributed*)

THE visitor to Paris who, walking along the Boulevard St. Denis, happens to glance down the Rue St. Martin, will notice, embedded in buildings on the eastern side of the thoroughfare, a conical-topped turret. This marks the site of a corner of the fortified wall which formerly surrounded the priory of St. Martin-des-Champs, established here during the eleventh century. While the fortified wall (save for a fragment adjoining the Rue du Vertbois) disappeared long since, the monastic church and the refectory of the priory still remain. We may, indeed, be thankful that these two buildings have survived, since both are of high archeological and architectural interest. There came a time—during 1851—when a certain tower within the precincts was scheduled for demolition. Pleading earnestly for its retention, Victor Hugo exclaimed: "Démolir la tour, non! l'architecte, oui!" In spite of this intervention, demolition of the tower proceeded, a comic touch being added by the fact that the architect responsible was the poet's own nephew.

Much of the area formerly covered by the priory of St. Martin-des-Champs is now occupied by the Conservatoire National des Arts et Métiers, not to be confused with the closely adjacent École Centrale des Arts et Manufactures, founded in 1829. The Conservatoire was brought here in 1799, five years after its foundation by the Convention, and a substantial fraction of the site of the priory is now occupied by the buildings which accommodate the Museum, Library, Instructional Departments, Laboratory for Testing Materials and the Bureau of Stan-

dards, these being the primary sections making up the Conservatoire National des Arts et Métiers.

The historical imagination will always be stirred by ancient buildings. Here at St. Martin-des-Champs the engineering imagination is also stirred as the visitor beholds structures which, dating from as early as the twelfth and thirteenth centuries, are now parts of a scientific institution wherein may be found not the relics of saints, but the apparatus of savants. While it is true that the world contains many venerable and beautiful library buildings, there is something entirely unique in the early Gothic structure—formerly the refectory of the monastery—which houses the technical library at the Conservatoire National. The architect was Pierre de Montereau (or Montreuil), who worked for St. Louis and under whom Gothic art has been said to have reached its culminating point. That he was an engineer as well as a consummate artist is seen in the support of the heavy vaulting by the row of seven slender pillars, an arrangement whereby



CONSERVATOIRE NATIONAL DES ARTS ET METIERS

the residual lateral thrust of the vaulting could be imposed on the walls without assistance from flying buttresses or buttresses. The refectory of St. Martin-des-Champs (which retains the original stone reading pulpit) may not be ideal as a place for storing books and for reading them. It is, nevertheless, a building of surpassing charm, impressing upon the visitor a sense not only of proportion, but of solemnity. Contemplating this thirteenth century masterpiece the visitor will learn without surprise that "Au réfectoire de St. Martin-des-Champs, Pierre de Montereau utilise la pierre et lui applique les lois de la mécanique avec une science de ses resources si consommée qu'il faudrait y substituer le métal pour aller plus loin."

Close to the refectory is the conventual church of the priory, a building dating, in parts, from the twelfth century and now used as a museum. At the entrance to the ambulatory stands the historic steam road locomotive constructed by J.-N. Cugnot in 1770–1771, after a smaller prototype tested in 1769. This single-wheeled steam tractor articulated to a two-wheeled trailer—and thus the ancestor of the now familiar mechanical horse—is indeed a venerable relic and, we read that the smaller prototype overturned when rounding a corner near where now stands the Madeleine. The ratchet type driving gear (a form of transmission described by Denis Papin in 1669) operated by the two single-acting vertical cylinders appears to have been renewed, the locomotive having been in a serious state of decay when acquired by the museum. While the second of Cugnot's locomotives is believed to have given better results than the first, it, too, was abandoned after road tests. Cugnot, reduced to extreme poverty, received aid from Napoleon and others, and we are glad to read that the old man's closing years—he died in 1804—were rendered comparatively comfortable. The sight of his celebrated self-propelled vehicle standing in the ambulatory of a twelfth-century monastic church conveys an impression of sublime incongruity. It is as if the "Rocket" were preserved, not in the Science Museum at Kensington, but in the chapel of Edward the Confessor at Westminster Abbey!

Alongside Cugnot's locomotive is a steam-driven automobile built by Amadée Bollée père, a car which, in 1875, covered the distance from Le Mans to Paris (230km) in eighteen hours. Adjacent is Bleriot's historic monoplane, which, powered by a 25 h.p. air-cooled motor, flew from Calais to Dover on July 25, 1909, the historic first crossing of the Channel by aeroplane. This was not, as has been commonly supposed, the first aerial crossing of the Channel, since as long before as January, 1785, the Channel was crossed by a balloon, the aeronauts being John Jeffries and Jean-Pierre Blanchard. Amid numerous other machines of technical and historic interest is an early Bisschop gas engine constructed by Rouart frères. All these pieces are preserved in the ancient conventual church of the priory. Elsewhere in the museum we can see that famous calculating machine which was devised by Pascal—then twenty years of age—while assisting his father in the collection of taxes at Rouen. This was the first attempt to produce a machine which would work out, automatically, arithmetical problems involving tedious calculations. We also find here—fenced off for its better protection—some of the apparatus used by the illustrious Antoine Laurent Lavoisier in his epoch-making experiments. To many visitors this apparatus may prove more moving than any other of the exhibits in the museum, and they will not need to be reminded that on May 8, 1794, the head of Lavoisier was shorn off by the guillotine. "The Republic," it was said, "had no need of savants."

The student of technology will be attracted, at the Conservatoire des Arts et Métiers, by certain statues which are to be found here, conspicuous among them being a charming representation of Denis Papin standing beside a reproduction of his digester and safety valve. The entire atmosphere of the buildings, their contents and their surroundings, recalls to mind many of those great Frenchmen whose names illumine the history of science. Opposite the main entrance to the Conservatoire are the Rue Salomon de Caus and the Rue Papin; alongside is the Rue Réamur. It is as if the Science Museum at Kensington could be approached along Newcomen Street instead of by way of the unromantically named Exhibition Road. The French have much to teach us in respect of that inspired sense of the appropriate, which, used imaginatively, becomes none other than a source of inspiration.

While the École Centrale des Arts et Manufactures adjoins the Conservatoire National, we have to move to the left bank of the Seine to find the École Polytechnique, which—very appropriately—is located in the Rue Descartes. This is the oldest and most eminent institution of the kind in France and here it was that N.-L. Sadi Carnot was a student. Still a residential military school in which the students wear uniform, teaching in the École Polytechnique is entirely mathematical and theoretical and graduates are no longer precluded from taking up civilian work. Together with the École Polytechnique and the École Centrale des Arts et Manufactures, Paris contains the long-established École des Arts et Métiers, a technical high school for the training of engineers, the duration of the course here being four years. These famous schools, to say nothing of the instructional section of the Conservatoire National, afford impressive evidence of the age and magnitude of the facilities provided in Paris for the education of engineers. Indeed, though the visitor to Paris has many things on which to meditate, he will, if he is also a student of the history of technology, derive peculiar delight from the contemplation of institutions symbolic of that great stream of technical genius which has flowed for so long and so fruitfully in France. One of our English philosophers has remarked that whatever widens the imagination and enables it to realise the actual experience of other men is a powerful agent of advance. This is as true in science as in ethics, and we see a noble illustrative example in the Conservatoire National des Arts et Métiers, where the unique association of the ancient with the modern, the æsthetic with the practical, renders the institution one of the shrines of French civilisation.

Continuous Brass Strip Mill at Waterbury, Connecticut

No. I

AT a cost of more than 10,000,000 dollars, the Scovill Manufacturing Company, of Waterbury, Connecticut, has recently installed a new continuous brass strip mill. From its utilisation of a high-capacity continuous slab casting process to the employment of universal spray pickling lines, this integrated mill comprises a number of interesting innovations in brass processing technology, and is capable of producing the heaviest cold-rolled brass coils, which are currently in commercial use in the American brass industry.

The company is generally considered to be the oldest as well as one of the largest brass-producing companies in the United States; its business having been established in the Naugatuck Valley in Connecticut almost 150 years ago. Through the intervening years since the founding of the company, the manufacturing operations have changed considerably and, to meet these changes in production, the works at Waterbury grew into an accumulation of buildings and facilities, which, although suitable to meet the manufacturing problems of any given period, resulted in a mill which was no longer able to meet the requirements of modern mechanised operation, particularly with regard to brass cold-rolling. In July, 1943, the company engaged the Stone and Webster Engineering Corporation, of Boston,

to make a study of its strip rolling mill operations with a view to the ultimate design and construction, as soon as the lifting of the existing wartime restrictions would allow, of a modern strip rolling mill. This study continued intermittently from 1943 until the early part of 1947, by which time plans had been finalised to such an extent that the construction of a new mill was authorised. It was apparent already from the earliest studies that substantial production economies could be obtained by processing large and heavy units of cold-rolled brass and sheet strip rather than small light-weight units. Because the equipment in the existing mill was inadequate for the efficient processing of large bars or coils and because of the lack of mechanised material handling facilities, production in the existing works was limited to bars and coils weighing not over approximately 350 lb each and of a size which could be handled manually by one or two men. This condition, together with the anticipated post-war increase in demand from customers for longer strip than had been furnished in the past, determined initially that, for purposes of the study, normal production would be considered to consist of bars 16in wide and weighing approximately 1500 lb each. However, after further investigation, it was decided to base the design of the equipment on a maximum width of 28in, permitting bars heavier than 2000 lb to be processed. The new continuous strip mill building occupies an area 1400ft long by 140ft wide, and comprises two parallel and adjacent bays, one 80ft wide and the other 60ft wide. For purposes of equipment servicing and maintenance and of occasional materials transport, the 80ft bay is equipped with one 15-ton crane and three 10-ton cranes and the 60ft bay with two 10-ton cranes and one 7½-ton crane. There are two motor-driven transfer bogies to facilitate the comparatively small amount of transport of material which is required between the bays. A maintenance machine shop, which covers an area of 385ft by 77ft, is situated adjacent to the 80ft bay. Another adjacent building contains the three electric melting furnaces and the continuous-casting machine which supplies the slabs for the strip mill. The general sequence of operations can be seen readily from the accompanying diagrammatic flow chart (Fig. 1).

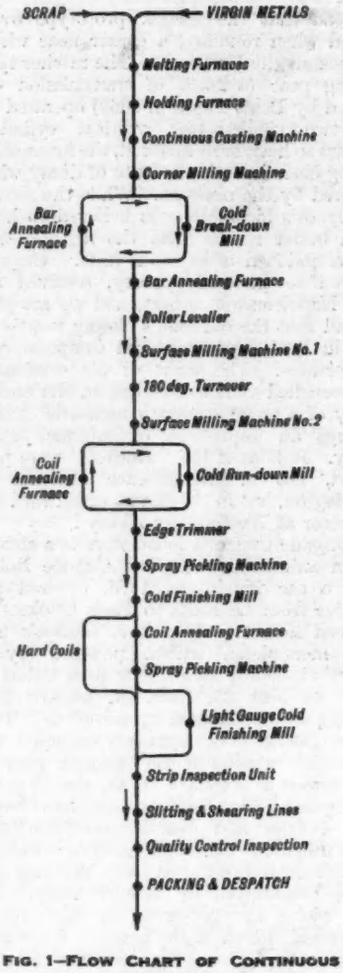


FIG. 1—FLOW CHART OF CONTINUOUS STRIP MILL

INDUCTION MELTING FURNACES

To supply the large amount of molten metal required for continuous casting purposes, three Ajax-Scomet low-frequency induction melting furnaces, each having a rated capacity of 1000kW, were installed. The furnaces are each capable of holding a maximum charge of 22,000 lb and have a melting rate of approximately 10,000 lb of brass per hour. Temperature control is automatic by means of thermocouples, which are inserted permanently. Details of the furnace design are illustrated in the sectional views reproduced in Fig. 2. The furnace consists of a steel drum *A* with a refractory lining *B* of pre-fired shapes and standard bricks. Three detachable inductor units, *C*, *D* and *E*, which have a rating of 333kW each, are fastened to the lower part of the drum and generate heat within the melting channels *F*, *G*, *H* and *K*. The melting channels form two secondary loops, which are interlaced with two primary coils *L* and *M*, surrounding a closed transformer core *N*. This circuit may, thus, be considered as the secondary winding of a short-circuited transformer. A current of several thousand amperes flows through the melting channels, with the heat being dissipated to the cold metal contained in the drum. The inductor units can be detached and replaced without interrupting the operation of the furnace. Each inductor unit has two blowers *O*, with a capacity of 1250 cubic feet per minute, required to cool the transformer core and the primary windings. The drum is rotated by means of a motor driving through a reduction gearbox *P* and two chains *Q*. On both ends of the drum, two tyres *R*, supported by rollers *S*, are provided. This device facilitates the rotation of the drum to discharge metal through the pouring spout *T*.

The three furnaces, comprising this installation, are claimed to be the largest made for the melting of brass. Their high efficiency is due mainly to the fact that the volume of metal is large relative to the area through which it may lose heat and due also to the unusual thickness of the refractory, which lines the furnaces. The metal holding capacity of the

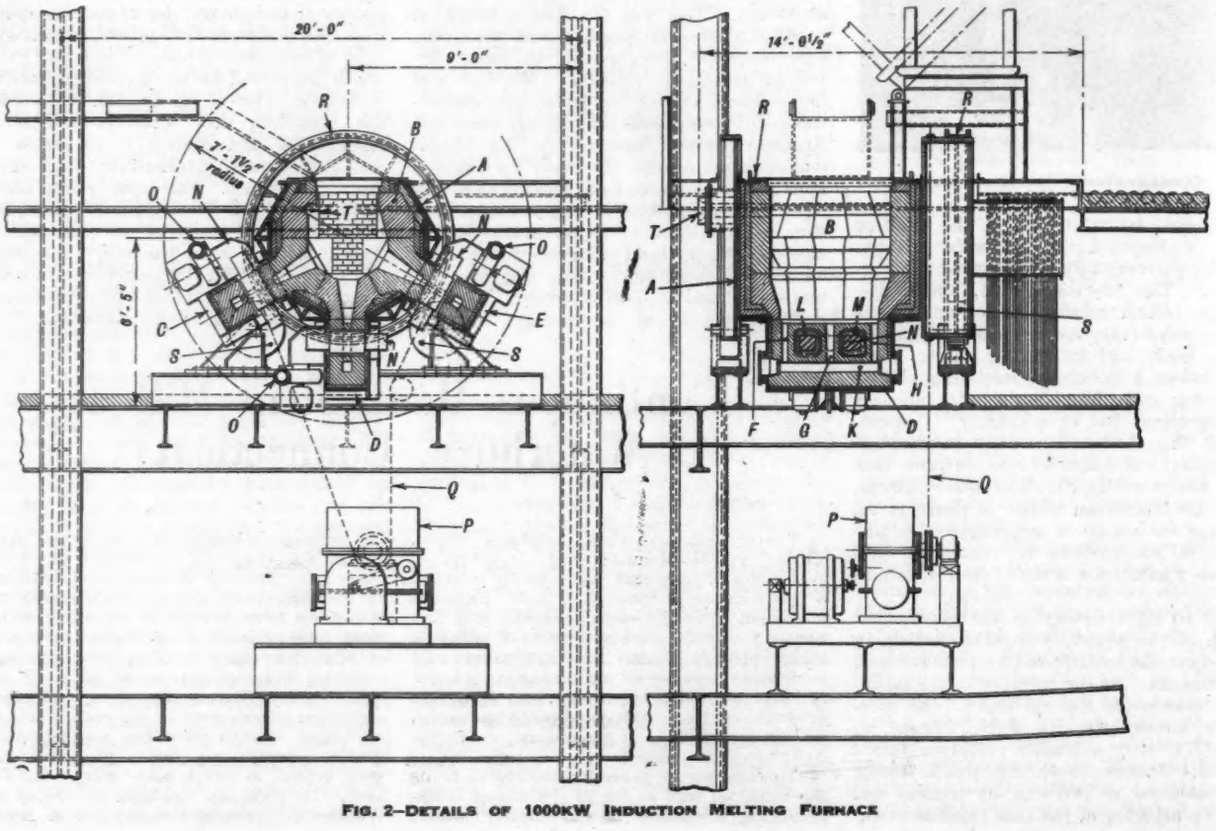


FIG. 2—DETAILS OF 1000kW INDUCTION MELTING FURNACE

FIG. 3—DISCHARGE OF SLAB FROM CONTINUOUS CASTING MACHINE

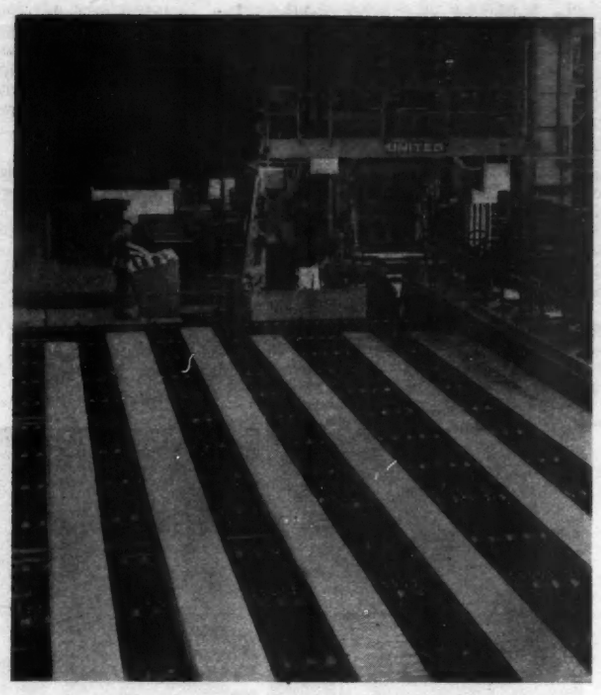


FIG. 5—FOUR-HIGH RUN-DOWN MILL

furnaces was reduced deliberately as much as possible in order to facilitate the rapid change of alloys, which is a requirement of considerable importance in a brass mill. A particular advantage of the furnaces is their ease of operation. Charging is accomplished with a variable speed vibrating hopper, which permits the dumping of large amounts of virgin metals and scrap of all kinds into the furnace. This arrangement facilitates close control of uniformity and composition of the metal.

CONTINUOUS SLAB CASTING

The Junghans-Rossi continuous slab casting machine of the company is the only unit of its kind in operation in the U.S.A. at the present time, and in Fig. 3 the lower end of the machine can be seen with a sawn-off slab about to be laid on the receiving table. The holding furnace at the top of the machine has a capacity of 9000 lb and contains a 120kW induction unit to maintain the molten metal at the desired temperature. The furnace is equipped with two diametrically opposite sets of spouts, each set consisting of a pouring down-spout, a receiving funnel and an emergency dump-spout. When the machine is in operation the furnace is inclined 25 deg., and the front down-spout is submerged in liquid metal in the mould. When not in operation the furnace is maintained in a horizontal position, and both down-spouts are inclined at 25 deg. to the vertical, their openings being above the liquid metal line. A diagram showing the layout of the continuous casting unit is reproduced in Fig. 4. The down-spout is an inverted T with holes in the bottom to facilitate proper distribution of metal in the mould. The pouring rate of the molten metal through the down-spout is controlled by a needle valve extending through the top of the holding furnace. If pouring difficulties are encountered, the furnace is tilted back to the horizontal, revolved through 180 deg. to bring into position the opposite down-spout, and tilted once more to recommence casting. The water-cooled copper mould, which is 25in long, has a vertical reciprocating movement, the rate of the downward stroke being synchronised with the discharge rate of the bar, and the rate of the upward stroke being three times that of the downward stroke. Altogether, the vertical travel of the mould per reciprocating cycle may be varied between a minimum of $\frac{7}{16}$in and a maximum of 1¼in. The bar or slab is removed from the mould at constant speed by means of a set of withdrawing rolls, the speed of the rolls being synchronised with the rate of the downward stroke of the mould. The 32in diameter saw, which cuts the slabs to the desired length, is hydraulically clamped to the slab during the cutting operation, thus allowing the whole saw assembly to move down at slab speed. The sawing time required for a 25in by 2½in slab of non-leaded material is approximately 35 seconds. The machine is capable of casting slabs up to 29in wide and 2½in thick; the average size of the slabs is 24in wide, 2½in thick and 10ft long.

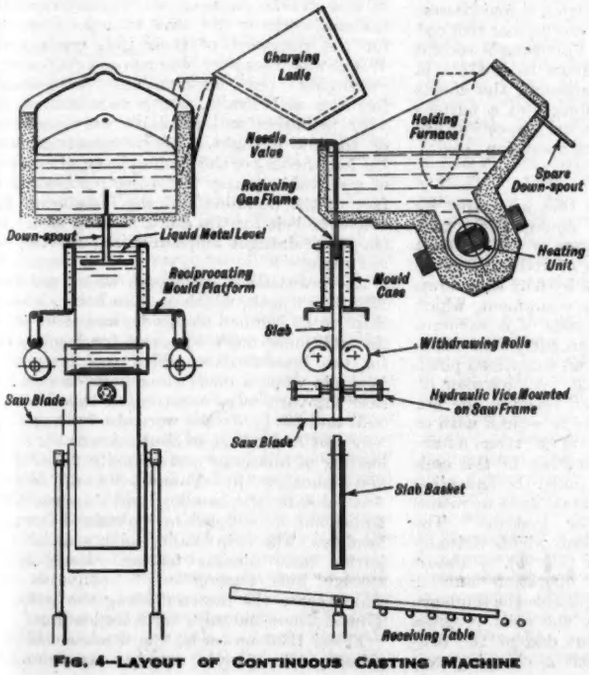


FIG. 4—LAYOUT OF CONTINUOUS CASTING MACHINE

Operation of the unit is in accordance with the following sequence. A 5000 lb charge of metal is assembled on the ground floor, hoisted to the third floor, and dumped into the vibrating hopper, which feeds it automatically into one of the three induction melting furnaces at a controlled speed and at predetermined intervals. When ready to pour, the metal is tapped into a 5000 lb ladle, transported to and poured into the holding furnace feeding the casting machine. The metal is poured from the bottom of the holding furnace through the distributor into the mould, being discharged at an even and controlled rate below the surface of the pool of molten metal. This pool is maintained at an even level at all time. A constant gas flame at the top of the mould prevents excessive oxidation of the surface of this pool of molten metal. The metal descends at a constant speed through the mould, emerges as a solid slab, passes through the withdrawing rolls and is cut to length by the saw. A basket catches the slab after cutting and deposits it on the roller table. Finally the slabs are inspected, tested, and sent to the continuous strip mill for cold-rolling operations.

THE BREAKDOWN MILL

After passing through the initial corner milling operation the slabs are ready to be transferred to the 30in by 36in two-high Farrel-Birmingham cold breakdown mill. Completely mechanised handling equipment makes it possible for only two operators to manipulate the slab on both sides of the mill and to regulate the rolling speed and the mill opening. The control devices are provided in duplicate at two desks, placed on either side of the mill on

opposite sides of the roller tables. For slab handling vacuum pilers and unpilers travel over the entry, delivery and transfer tables. These units each consist of a series of suction discs mounted on a structural supporting member, which is actuated hydraulically. On the entry side the routine procedure is to lift the slabs from the transfer table to the entry table of the mill, where a hydraulic stacker is installed to ensure positive entry of each bar into the roll bite. On the delivery side a kick-off device removes the bar after the pass to one of the transfer tables situated on each side of the delivery table. To accommodate varying lengths of slabs, there are eight of these air-operated kick-off arms, set at different centres, all mounted on a shaft beneath the table. From the transfer tables on the delivery side of the mill the bars are stacked by vacuum pilers. By means of chain transfers the stacks are then either returned to the entry side of the mill for a succeeding pass or delivered to the bar annealing furnace. Limit switches interlock the tables on both sides of the mill.

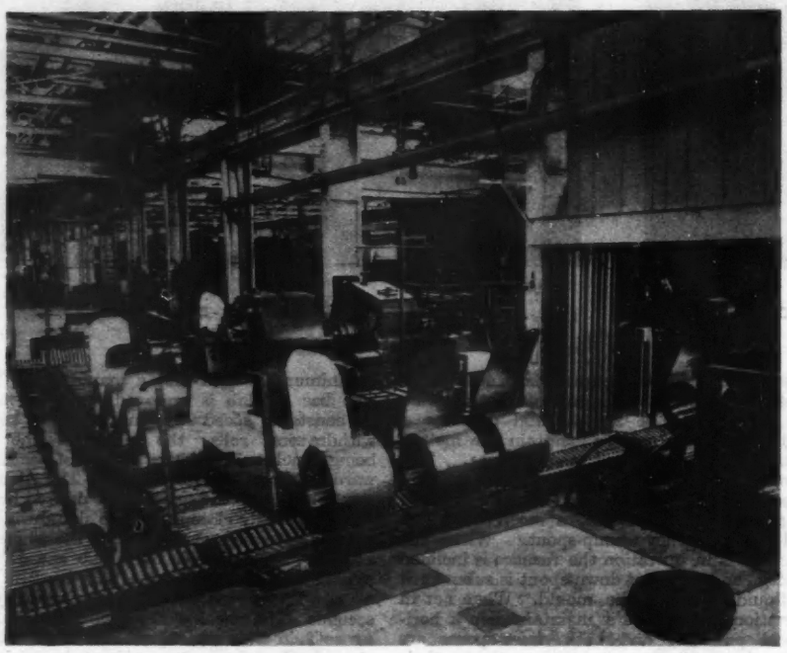


FIG. 6—COIL CONVEYOR LOOP

The housings of the mill are cast steel and are mounted on cast steel stringer bed-plates. The twin-motor screwdown of the mill is equipped with a magnetic clutch, which facilitates the independent operation of either screw and the simultaneous adjustment of both. Two large dial indicators are mounted on the housings at the entry side for gauge readings. Each indicator has two hands: one for thousandths and one for fractional divisions of an inch. In addition, Selsyn units on the entry control desk indicate the mill opening in thousandths of an inch. The two mill rolls of forged steel have their necks supported in "Morgoil" sleeve bearings. The top roll is hydraulically counterbalanced by means of cylinders on the underside of the mill housings, which support the roll against the adjusting screws through lifter rods. The balancing system includes a nitrogen-loaded accumulator maintained at predetermined pressure by a positive displacement pump. To facilitate the changing of rolls an electrically driven roll-changing rig is recessed in the floor on the side of the mill opposite the drive. In preparation for roll removal, spacers are used to support the upper roll chocks on the lower ones, and the rolls, still in their bearing boxes, are readily removed from the mill as a pair and a new set installed in like manner. Universal spindles are used to connect the rolls to the pinion stand. In the spindle assembly 2½in diameter solid steel rods serve for the upper spindle support, and for horizontal alignment there are used two hollow steel bars, which pivot in brackets attached to the housing of the pinion stand.

The combination drive and pinion stand drives the mill at either 90ft or 180ft per minute. The first reduction gears and the mill pinions are Farrel-Sykes continuous-tooth herringbone gears, while the second reduction set consists of divided double helical gears. A pressure lubricating system with a separate motor-driven pump provides a continuous spray of oil at the mesh line of all gears and pinions and forced feed lubrication to all anti-friction bearings. The pinion stand housing is of cast "Mechanite" metal and the base and cover for the drive are heavy steel weldings. The mill drive is obtained from a General Electric wound-rotor induction motor having a continuous 2000 h.p. rating at either 360 or 720 r.p.m.

Slabs enter the breakdown mill at a thickness of 2¼in and are reduced to 1·380in in four passes. After a process anneal they are further reduced to 0·790in in two passes. Following a second annealing they are rolled down to 0·415in in two passes. After final annealing the sheets pass through a roller levelling and a surface milling operation and after an inspection are ready for the run-down rolling operation.

THE RUN-DOWN MILL

The run-down mill is a 16in and 34in by 34in four-high United cold-rolling unit operating within a speed range of 0/400/1000ft per minute. It is capable of rolling 2000 lb bars 29in wide and ⅛in thick by 68ft long down to coils 0·050in thick. The equipment, which is illustrated in Fig. 5, consists of a vacuum-cup crane to place bars on an entry feed table, which transports the bar to an entry feed pinch roll unit in front of the mill. An upcoiler on the delivery side of the mill receives the bar and coils it. These coils can be wound with or without a tail depending upon their subsequent processing. The handling of the coils at and between the rolling mills, the annealing furnaces and the pickling units is done by means of comprehensive conveyor systems. The whole of the conveyor system, which virtually forms a loop storage area (Fig. 6), is almost completely automatic in operation and is fully interlocking to make possible the sequence operation of equipment as the coils progress around the mill. The front end of the run-down mill is provided with a charging car, to take coils from the conveyor system and deposit them in a coil-box to be fed to the mill through pinch rolls and sticker entry guides.

The run-down mill may also be operated as a finishing mill, when coils are fed into the mill from an expanding pay-off reel on the entry side. Furthermore, for such operation a wedge-type expanding and collapsing reel is employed on the delivery side of the mill. This reel is equipped with a belt wrapper for introducing the front end of the coil around the reel at mill speed.

(To be continued)

Development of the Steel Industry in Australia

(Contributed)

CONCURRENTLY with the ceremonies which have taken place this year in Australia to commemorate her fifty years of nationhood, the Broken Hill Proprietary Company, Ltd., has been celebrating the jubilee of another event of great historical importance to that country. For it was in January, 1901, that a party of workmen landed at Whyalla, in the Spencer Gulf, South Australia, to establish a settlement there and construct a 32-mile trolley way linking the harbour with the Iron Knob iron ore deposits. The landing of these pioneers was, in fact, not only the beginning of the vast development of this great company—merged since 1935 with Australian Iron and Steel, Ltd.—but also the first stage of the development of secondary industries in Australia. Over a million and three-quarter tons of steel are now produced each year by the two plants at Newcastle and Port Kembla, and a major project is in hand at the Australian Iron and Steel, Ltd. works at Port Kembla for the construction of a hot and cold strip mill and a tinplate plant, which involves the reclamation of a large portion of the harbour area. When completed, the output of steel will be increased by another half million tons, though if more coking coal were available now, a considerable increase in output would be possible, even with the existing plants. At the present time, the output is insufficient to meet requirements.

Since it was decided in 1911 to begin the production of steel, the history of the company has been one of unceasing progress and development. Newcastle, in New South Wales, near suitable coal sources, was selected as the obvious site for the iron and steelworks, but in view of its great distance from Whyalla—a distance by sea of 1150 miles—it was equally clear that the steelworks would have to depend on ships for the transport of their iron ore supplies. Work was therefore commenced at once on improving the ore-handling and loading facilities at Whyalla, which were at that time very primitive and available only to vessels of shallow draught. Improvements included the lengthening of the loading jetty, the erection of a movable gantry for projecting beyond the face of the dolphins and the installation of a conveyor belt for the quick loading of ore into the deep draught ships required for the long sea voyage.

At Newcastle a steelworks wharf was built, 2225ft in length, which enables five or even six ships to be berthed alongside, and there is now an additional 500ft of wharf for loading coke for the blast-furnace which was installed at Whyalla when a deep-water harbour and first-rate shipyard were constructed there between 1937 and 1941. Jetties were also built at Rapid Bay and Ardrossan, in South Australia, for the loading of limestone and dolomite respectively, and another in Yampi Sound, Western Australia, for the handling and shipment of the additional ore supplies now obtained from that locality. The ship-loading plants at all three jetties have similar features—large-capacity storage bins feeding on to conveyor belts which carry the material along the jetty to a T-head where the ships berth for loading.

From 1930 onwards, the Broken Hill Proprietary Company's steady expansion was

rapidly accelerated. Considerable plant extension and modernisation took place at Newcastle and, after the merger of this company and Australian Iron and Steel, Ltd., in 1935, plans were immediately drawn up for the extension of the latter's works at Port Kembla and the rationalisation of the steel industry's two plants for maximum production and efficiency. Later came the major feat of dredging and constructing a deep-water harbour, a blast-furnace and a shipyard at Whyalla, followed by the erection of a shell manufacturing annexe, a toolroom and electric steel forge plants at that port. In a speech at the recent jubilee celebrations at Whyalla, Mr. Playford, Premier of South Australia, welcomed the establishment there of industries which are of the greatest importance. In an age of atomic warfare, he added, it would be a mistake to have the country's industrial strength centred at one place and least of all on a part of the seaboard not easy to defend.

Throughout the first world war the company depended on a fleet of chartered ships to carry the iron ore to Newcastle and transport the finished steel products to Melbourne and Adelaide on the return voyage, but the U-boats' crippling toll of the world's shipping had made steamers extremely difficult to obtain. The decision was therefore made to establish its own shipping organisation, and by 1925 the company owned five ships (six had been purchased, but one was wrecked in 1923), which made the Newcastle-Whyalla round trip in about twenty-one days, with 5500 tons of iron ore. On the outward trip from Newcastle they carried steel products to Melbourne and Adelaide or steel and coal to Port Pirie and Port Augusta, in South Australia. Four more ships were ordered from Lithgow's yard at Glasgow during 1935 and 1936, each capable of carrying 7500 tons of ore, with a speed of 12½ knots, and by 1938 the company had a fleet of eight ships with a total deadweight carrying capacity of 56,700 tons—the largest Australian-owned and operated coastal line, employing 380 officers and men. In the three years 1936–39, the annual iron ore production rose from under 2 million to a record of over 2½ million tons, and in the same period steel ingot production at Newcastle and Port Kembla jumped from 850,000 to 1,176,000 tons—most of it carried in the company's ships.

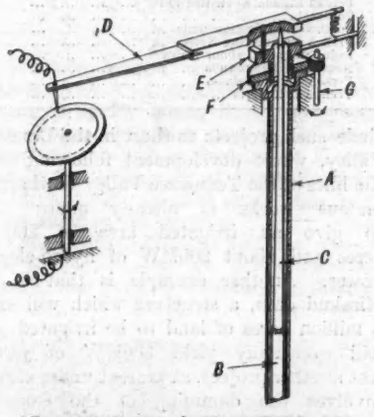
Two of these ships were lost in the second world war, but even before 1939 the company had foreseen the need for additional shipping. With the shipyard established at Whyalla it was decided to enter the shipbuilding business, despite the fact that the company had already agreed to comply with the Australian Government's request to build naval patrol vessels. The keels of two new ore carriers—slightly larger than the Scottish-built vessels—were laid at Whyalla in 1941, and, since the war, four more ships have been laid down there, two of which are already in service. The last four vessels are of 12,500 deadweight tonnage and are the largest ships to be built in Australia. They follow the company's own design for the transport of iron ore from the deposits in Yampi Sound, Western Australia, to the Newcastle and Port Kembla Steel Works, a round trip of some 6000 miles. They incorporate self-trimming holds, cargo handling gear capable of lifting up to 30 tons, mechanical stokers, especially designed ventilation systems and ample refrigerating space for ship's stores as well as for meat, dairy produce and vegetables for the settlement in Yampi Sound.

A characteristic of these vessels is their exceptionally large water ballast capacity, totalling 4500 tons, for the long ballast voyage to Yampi Sound and to provide fresh water for the settlement there—a provision originally required for industrial and domestic purposes at Whyalla before the completion of the Morgan–Whyalla pipe-line during world war II. Although the turbines and gearing for the first ship were imported, the turbines for the other three, and the gearing for two of them, are being built under licence in Australia, the work being shared by the Newcastle and Kembla Steel Works and Whyalla. Apart from the production of coal and steel for local requirements, the company, under the leadership of Mr. Essington Lewis, now chairman of the board of directors, has clearly made a valuable contribution to the industrial potential of the Commonwealth and Empire by the creation of the industrial establishments at Whyalla.

An Accurate Temperature Controller for Electric Furnaces

The accompanying illustrations show the principles of operation and the general arrangement of a temperature controller designed to maintain constancy of temperature to within ±0·5 deg. Cent., in electric furnaces. The apparatus is made by Alfred J. Amsler and Co., Schaffhouse, Switzerland, and is marketed in the United Kingdom by T. C. Howden and Co., Leamington Spa.

As illustrated in the diagrammatic sketch,



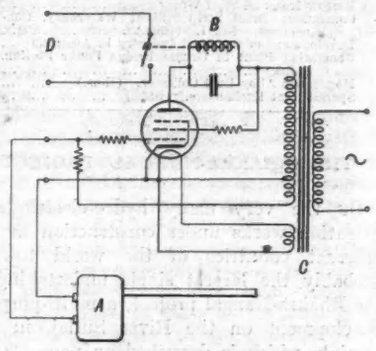
DIAGRAMMATIC ARRANGEMENT OF TEMPERATURE REGULATOR

the Amsler temperature controller operates because of the unequal thermal expansion of a quartz rod *B* and a heat-resisting steel support *C* mounted in a tube or feeler *A*, which is also of heat-resisting steel. When the feeler is heated in the electric furnace the tube *A* expands more than the quartz rod *B*, the difference being transmitted to a lever which is supported without friction on its base piece *E* by means of a piece of strip metal. Fitted to the free end of the lever is a thin leaf spring *D*, carrying a contact tip. This tip bears against a rotating disc which is inclined with respect to its driving axle. Because the rotating plate is inclined it remains in contact with the tip over an arc (shown solid in our diagram) and breaks contact over the remaining arc (shown dotted). The ratio between the two arcs depends on the vertical position of the contact tip and therefore on the temperature of the feeler.

Through the medium of an electronic relay the circuit is arranged in such a way that the furnace is switched on while the contact tip is touching the plate and is switched off when the contact is broken. Therefore, if the furnace temperature rises the arc of contact (and the time during which the furnace is switched on) becomes shorter, which tends to restore the temperature to its preset value. Conversely, if the temperature falls the furnace current remains switched on for a longer period and again the departure from normal temperature is corrected. Setting of the desired temperature is effected by a pinion *G*, which engages with a toothed nut *F* and thereby transmits vertical adjustment to the base piece *E*.

Since the time taken for the disc or "wobble plate" to make one revolution is relatively short—about ten seconds—the temperature changes during one revolution or switching cycle are negligible, and the contact tip, therefore, remains in a position corresponding exactly to the average temperature. Since the duration of the "on"/"off" period is regulated during each ten-second cycle, deviations from the desired temperature are kept to a minimum, which is an important consideration in furnaces that may have a high thermal inertia coefficient.

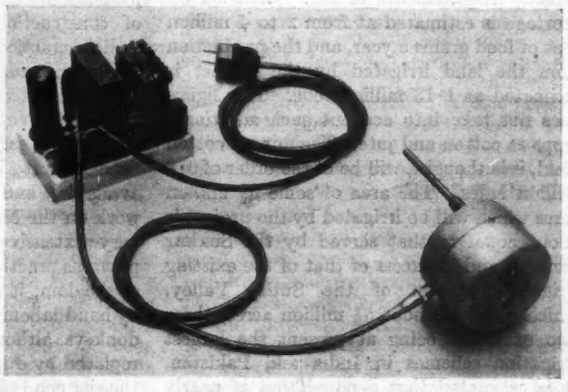
The rotating contact controls an electronic relay, which is connected as shown in the accompanying diagram and, in turn, controls the power supply to the furnace. When the rotating contact of the temperature regulator *A* is open the valve is non-conducting. When the contact is closed the anode current increases and the relay *B* is actuated; a switch designed for the furnace loading is connected to the terminals *D* for switching the furnace current



ELECTRONIC RELAY

"on" and "off." The valve functions as an amplifier and rectifier, taking alternating current from the transformer *C*.

The photograph reproduced herewith shows the electronic relay assembly on the left and the temperature regulator, housed in its light alloy casing, on the right. Temperature adjustment is made on the knob, which can be set in association with the graduated scale to provide the fine setting, while the window below the knob provides the coarse reading. There is a second adjustable auxiliary contact fitted in the regulator casing, whereby the supply voltage can be switched off when the temperature rises or falls below a predetermined value. This limit switch can be adjusted to operate for a deviation from normal temperature of 5 deg. to 30 deg. Cent.



TEMPERATURE CONTROLLER

The working temperature range of the controller is specified as −200 deg. Cent. to +1000 deg. Cent. The normal accuracy over the working range is given as ±0·5 deg. Cent. Greater accuracy over narrower temperature ranges can be provided, if required. Four lengths of feeler—90mm, 130mm, 190mm and 280mm—are available, the operative length being 60mm in each case. The electronic relay is suitable for single-phase line voltages of 220V and 110V, 40 to 60 c/s.

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THE BHAKRA-NANGAL PROJECT

Of the very many hydro-electric and irrigation works under construction in the different countries of the world to-day, probably the largest single undertaking is the Bhakra-Nangal project, a multi-purpose development on the River Sutlej, in the Punjab, which is described on page 170 of this issue. Apart from its technical interest, the project is of particular importance because of its economic effect in making possible the development of agriculture and industry over a wide area. It has been estimated that the wealth produced in a single year of full operation, although difficult to convert into terms of money, will exceed the total capital cost. The project thus provides an impressive example of the fundamental value of civil engineering works of this kind in many countries where irrigation, flood protection and soil conservation are amongst the primary requirements of life. India's food shortage is estimated at from 2 to 4 million tons of food grains a year, and the production from the land irrigated by the project is estimated at 1·13 million tons. This figure does not take into account such additional crops as cotton and jute. The annual cotton yield, it is thought, will be of the order of 0·8 million bales. The area of some 6½ million acres which will be irrigated by the project is about equal to that served by the Sukkur barrage, and in excess of that of the existing irrigation system of the Sutlej Valley, which supplies about 5½ million acres, these two examples being at present the largest irrigation schemes in India and Pakistan. It is estimated that a population of nearly three million will live on the irrigated area. As the population grows towards that figure, so it is expected that industries will be established—perhaps fertiliser factories, cotton mills, and so on—and provide a market for the continuous supply of 400MW of power which the project will be able to produce.

The Bhakra-Nangal project, although the largest in India at the present time, is one of twenty or thirty major developments, in the construction of all of which similar problems will have to be faced. They include such projects as those in the Damodar Valley, where development following along the lines of the Tennessee Valley Authority's famous works is already under way, to give an irrigated area of 200,000 acres and about 200MW of hydro-electric power. Another example is that of the Hirakud dam, a structure which will allow a million acres of land to be irrigated, and will eventually yield 300MW of power. Yet another project, at present under survey, involves the damming of the Godavari River in Madras, thus controlling a catchment of 121,500 square miles, an area greater than that of the United Kingdom. Apart from these new works, India and Pakistan together already have under irrigation an area of some 70 million acres, nearly as large as that of the whole of the irrigated lands of the rest of the countries of the world taken together, so that it is evident that a major source of wealth to those countries lies in the development and control of the resources of their rivers. But if all of these great projects are to be carried to completion, methods of construction that are foreign to past Indian practice will have to be used. The use of manual, rather than mechanical, labour has always been extensive in India. But for the construction of the works of the Bhakra-Nangal project great efforts have been made to increase the mechanical plant available, and the mechanisation of the work on the Nangal dam has been relatively very extensive, and much in advance of previous practice in the Punjab. The left half of the dam, it is true, was excavated at first by hand labour, and the spoil transported by donkeys, although later on the donkeys were replaced by dumpers which greatly improved the site conditions. Five thousand men were employed here at the peak period. But the foundations of the right half of the dam were almost entirely mechanically excavated, and compressed air has been used extensively there for the first time in that area.

Such great developments are not without their hazards, in India, as a quotation from the official pamphlet on the Bhakra dam will illustrate. There is at present no demand for power in the Bhakra area. The pamphlet comments ingenuously: "Will there be a demand? This is the Frankenstein of faint hearts. The only answer is, there better be! Power is wealth. Power alone can eliminate drudgery from existence in this country." It is, in fact, by anticipating the demand by constructing such works as those at Bhakra and Nangal, that India hopes to achieve the fundamental objective of raising the standard of life of its population to a more tolerable level, and to remove the evils of poverty and famine. That objective is, however, made the more difficult to achieve in India and in other countries of S.E. Asia, that have similar problems, by an increase in population so rapid that it threatens to absorb all the promised increase of output without bringing about improvements in living standards. There are, of course, possibilities that the Governments concerned may be able to take measures to hold down the birth-rate, to improve upon traditional methods of soil cultivation, or the like. But the engineer's answer to the problem is the only one in which much confidence can be felt. It is to press upon Governments the need for rapidity in executing projects, so that the rate of expansion in output that follows upon their successive completion exceeds the rate of increase in minimum demand which is the consequence of the rise in population. For if the speed of development is not sufficiently high, the nightmare dreamed by Malthus may come true, and not S.E. Asia alone, but the whole world eventually may go hungry and diseased!

REDUCING PEAK LOADING

The inability of the British Electricity Authority to meet peak demands for electric power in winter—and sometimes in the spring and autumn, too—has become a subject for perennial discussion. The latest body to express its views on the subject is the Association of British Chambers of Commerce. Its memorandum, as befits the product of a body concerned with trade rather than with technicalities, eschews discussion of the more technical factors involved. The problem is seen through the eyes of a consumer of electricity. Emphasis is laid upon the point that the shortage of power is likely to persist not merely for a year or two, but for a decade at least; and that is a pertinent factor in relation to one of the Association's recommendations that "every possible means should be pressed for overcoming the technical and other objections" to "ripple and other controls as a warning system and a demand regulator." There is nothing unusual about two other recommendations, that nothing less than a rate of commissioning as high as can be achieved by plant manufacturers should be the aim of the B.E.A. and that "industrial load-spreading arrangements in co-operation with industry and commerce should be more widely extended." But the Association's fourth and final recommendation has the merit of indicating how the shortage of power cannot be considered in isolation from other factors. It is that "supplies of solid fuel for domestic space heating should be assured for coming winters as a major contribution to conserving electricity supplies during peak periods." The point, in fact, is made that if the domestic user has not enough fuel to light a coal fire or work a central heating plant he will inevitably turn to other sources of warmth such as the electric fire. In fact

that scarcity of coke which has led to the imposition of coke rationing is likely to be reflected in an increased demand for electric power.

To judge from the statements annually made since the war in economic surveys, the Government has consistently underestimated the rate of increase of productivity in this country. It has, by consequence, under-estimated, too, the rate of increase in demand for electricity and for coal. Thus, unless industry finds the means of economising in fuel usage and reducing peak load demand, the country may well find in the not distant future that its total output is becoming ruled, not so much by the ability of managements and men to devise and work systems of higher productivity, as by the amounts of power and fuel available! There is no doubt at all that there is still plenty of scope within industry for economies in fuel usage. But the reduction of peak load demand is a less simple problem. To what extent, apart from load spreading, is there scope for economising in the use of power? Obviously, even if it were not retrograde, there is no possibility of substituting manpower for electric power, for labour is already scarce and the way to higher productivity lies through the use of more, not less, machines. But is there not a tendency in developing improved methods of manufacture to give little regard to the amount of power used so long as manpower can be saved thereby and wage costs heavily reduced? The power consumed, no doubt, varies in accordance with the particular method of machining or fabrication chosen for a given product. Is there scope here, through a wise choice of method, for the making of economies in power usage? Researches into production techniques, such as those conducted by the Production Engineering Research Association, can often lead to quite startling reductions in cost. Is it not probable that they might effect economies in power usage, too? Certainly, if there is no great weight of other advantage supporting one method of manufacture rather than another, firms that are contemplating changes in method would do well to choose that which is least expensive in power.

Industry's methods of using power have, of course, a great bearing upon the height of the peak load. The other day, in the House of Commons, in a discussion on re-armament that was conducted with an unusual lack of party political strife and a more complete understanding of the technical problems than is usually shown, Sir Austin Hudson pleaded for an extension of the system of two-shift working in industry. He pointed out that the extension of such a system must economise the need for new machine tools and that, since the tools would be used more intensively, "overhead" costs, and therefore total costs, would be reduced. He added that, by double-shifting, peak loading of power stations must be reduced. Indeed, were it possible widely to extend the system of double-shift working the peak load troubles of the B.E.A. might well be ended. Unfortunately, although many firms have adopted the system and it is likely, to judge from the statements of the Minister of Supply in the same debate, to be quite widely adopted for armaments work, its further extension is hampered by shortages of labour, even more so by shortages of housing, and at least to some extent by the objections of some trade unions. Yet, if there are not to be widespread power cuts every winter for many years ahead, industrial firms will certainly need to get together more effectively than in the past to see in what ways the electricity load can be spread over the hours, particularly those of the night, when ample generating capacity is available and taken away from the daily periods of peak demand. The working of more than one shift a day is certainly one of the more desirable methods, since it combines the advantage of spreading the load with several others.

Obituary

C. A. MIDDLETON-SMITH

We have learned with deep regret of the death of Dr. C. A. Middleton-Smith, which occurred at his home, Mon Plaisir Lodge, Guernsey, on July 31st, at the age of seventy-two. He was Taikoo Professor of Engineering in the University of Hong Kong from 1912 until early in 1939, since when he had been living in this country.

Cades Alfred Middleton-Smith, who was the son of the late Mr. James Middleton-Smith, was born on February 4, 1879, and

C. A. MIDDLETON-SMITH

was educated at the Portsmouth Grammar School and the Royal Naval Engineering College, Keyham, Devonport. His first appointment after completing his engineering training was as an assistant engineer, for a few months in 1900, with the Plymouth electricity supply undertaking. Later in that year he joined the staff of Belliss and Morcom, Ltd., Birmingham, and for twelve months or so was chief assistant in that company's testing department. But Middleton-Smith's vocation was for teaching, and in 1901 he was appointed to the staff of Birmingham University as a lecturer and demonstrator in engineering. That appointment was the beginning of a distinguished teaching career, which continued for nearly forty years. Middleton-Smith left Birmingham in 1904, to become senior demonstrator at King's College, London, and three years later he transferred to the East London College, Mile End Road, as assistant professor of civil and mechanical engineering. He held that appointment for nearly five years.

Early in 1912 the University of Hong Kong began its work. The establishment of a university there had been advocated some years previously by Lord Lugard, the Governor of the Colony. A Parsee merchant, who had been resident in Hong Kong for many years, undertook to provide the main buildings, and British and Chinese and subjects of other nationalities subscribed to the original endowment fund. Sir Charles Eliot was the first Vice-Chancellor and Principal of the University, and Middleton-Smith was invited to become the first Taikoo Professor of Engineering. In this responsible task he revealed not only his outstanding teaching ability but all his characteristic zeal for improvement and development. When Middleton-Smith first went to Hong Kong he was assisted only by a few part-time lecturers; by the time that he retired in 1939 he had built up a teaching staff of twenty-eight full-time British members, all recruited in this country, and a number of Chinese lecturers and demonstrators. Middleton-Smith arrived at Hong Kong University to find that the first large batch of engineering students had to be set to work immediately in a department which consisted of a few unfurnished class-rooms and practically no laboratory accommodation. To his duties as professor there were soon added the responsibilities of Dean of the Faculty and consulting engineer to the University. For the next few years there was little respite for the new Professor. He had to organise courses of instruction, draw up syllabuses, frame rules and regulations, and supervise the erection of laboratories, students' hostels and staff accommodation. As an instance of Middleton-Smith's energy in his early days at the university, it is fitting to recall his mission to England in 1913, as a result of which a large quantity of machinery and apparatus was presented to the university by engineering firms in this country. Some idea of the development work initiated and carried through by Middleton-Smith can be gained from the fact that, whilst in 1912 the total revenue of the university was about 80,000 dollars, by 1939 it exceeded 1,000,000 dollars. Meantime, over 2,000,000 dollars had been spent on new buildings; British engineering firms and shipping companies had contributed gifts of machinery and free freight to the value of over £40,000, and both the local government and the British War Office had granted considerable areas of land for expansion. It must not be forgotten, however, that throughout the twenty-seven years of development and expansion, a high standard of teaching was maintained under Professor Middleton-Smith's capable leadership. The conferment of the honorary degree of Doctor of Laws by the University was a well-merited tribute to the work of Middleton-Smith during a tenure of office which extended for more than a quarter of a century. As a further mark of the esteem in which he was held he was also given the title of Emeritus Professor.

Dr. Middleton-Smith became an Associate Member of the Institution of Mechanical Engineers in 1904 and was elected to full membership in 1912. He was an honorary member of the Junior Institution of Engineers, was twice president of the Hong Kong Institute of Engineers and Shipbuilders, and was the first president of the University Engineering Society, the foundation of which he inspired. Moreover, he took a prominent part in the public and social life of the Hong Kong community during his many years of residence there.

To us, as to his former students and many friends at home and overseas, Dr. Middleton-Smith's death brings a feeling of personal loss. For many years he was a valued contributor to THE ENGINEER. During the greater part of his stay in Hong Kong he provided the "Far Eastern Engineering Notes," which regularly appeared in our columns, and, from time to time, special articles on engineering developments in the Far East. After his return home, we printed several series of his articles based on his intimate and detailed knowledge of engineering progress in the Far Eastern countries. They included "The Burma Road and Industrial Development in China," published in 1940; "The Hong Kong Centenary and Applied Science," and "The Engineer in Malaya," in 1941; "The Engineer in the East Indies," in 1942; "Engineers and the British Empire," in 1943; "The Engineer in India," in 1944, and "Engineering Developments in Asiatic Russia," which appeared in 1945.

Literature

Industrial Research in Switzerland—Its Institutional and Economic Background. By RONALD S. EDWARDS, in collaboration with CHARLES LA ROCHE. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 21s.

THE impact of research upon technical industry is a subject of such immediate interest and importance that we are glad to see an authoritative account, in the English language, of industrial research in Switzerland. Those who have studied Swiss industry in action and are familiar with educational and research methods in that country will surely agree with Professor Edwards and Dr. La Roche in their statement that a major factor in the industrial development of Switzerland lies "in the attitude of the people. . . . Their economy is based on a foundation of good education, both general and technical, and a belief in Samuel Smiles. The result is diligence, thoroughness and conscientiousness in development and production." But this—as we are sure the authors would agree—is not the whole story. We must look to the historical background, which, throughout some two thousand years, has imposed upon the Swiss a more or less continual struggle. The Swiss character was forged in adversity, an adversity which, by the sixteenth century had welded them into the toughest soldiers in Europe. Indeed, while they now export technicians and technical articles, they formerly exported soldiers, and they have brought to their industrial problems—which Professor Edwards and Dr. La Roche show to be severe—the tenacity which they formerly exhibited in battling with Romans, Burgundians, Austrians, French and other assailants. While this admirable essay does not deal with historical matters, its authors might with advantage have mentioned that to this day the immemorial necessity of national defence remains a very serious problem among the Swiss. We must not forget those statutory obligations according to which every Swiss citizen must do regular periods of military service from the year in which he reaches the age of twenty, until the end of the year in which he reaches the age of forty-eight. It is hardly possible, moreover, to assess the problems of contemporary Swiss industry without reference to the fact that during six years of the second World War an average of 142,400 men were called to the colours each year. In these six years each soldier did an average of 533 days' active service. During the war and the period immediately preceding it the Swiss expended 10,000 million francs upon armament and active service, a sum equivalent to 2500 francs per head of the population. These figures remove a common misunderstanding of the impact, on the Swiss economy, of the defence aspect, which is not without significant influence on education and technical industry. Another factor which must not be overlooked in a review of research in Switzerland is the influence of the interchange of professors between the German and the Swiss universities. It was, for example, this interchange which brought Clausius to Zürich during the period of his highest scientific activity. Similarly, the Swiss, when entering the heavy engineering industry, did not hesitate to seek the co-operation of engineers from Great Britain, an eminent example (alluded to in the book before us) being the selection of Charles Brown, whose work has proved so influential in the development of Switzerland as a leading machine building country. Professor Edwards has expressed the opinion that study of industrial research and development in Switzerland might yield important lessons for Great Britain. It is quite true, and it is also true that in Switzerland, as in Great Britain and everywhere else, the influence of basic education cannot be overstressed. One element in which the Swiss educational system has contributed to greater harmony in industry is found in the singularly democratic basis of the elementary schools. This has persisted throughout the century during which the admirable facilities for widely-diffused technical and scientific education have been built up. Of no country in the world can it be said more truly than of Switzerland that where there is education there is no distinction of class. This is certainly a very powerful factor in Swiss technical industry, particularly for the reason that both the historical background and the sustained efforts of educationists have tended to inculcate habits of work and study concurrently with a strong love of independence. Professor Edwards and Dr. La Roche would agree that whatever the institutional and economic background of industrial research in Switzerland, the main source of Swiss industrial success is to be found in the capacity of the people themselves. How else could a country almost entirely without coal and other essential raw materials have reached the eminent industrial stature attained by Switzerland?

While the Swiss have been blessed with certain examples of what Confucius, nearly two thousand five hundred years ago, called the highest class of man—distinguished by the philosopher as those whose knowledge is innate—the Cantons have never been short of men belonging to what Confucius describes as the next highest class: those whose knowledge is acquired by study. The primary function of technical (or any other) education is to provide a supply of men in the second category, it being beyond the power of any educational system to produce men in the first category. In all countries, however, there are masses of people who belong to neither category, people divided into two main groups: (A) those who, with small mental endowments are yet willing to strive, and (B) those who will make no effort at all. It is no exaggeration to claim, for the Swiss, that among the able-bodied citizens of the Confederation one rarely comes in contact with representatives of category (B). We venture to suggest that Professor Edwards and Dr. La Roche have not sufficiently indicated the admirable efforts made by Swiss technical industry with a view to broadening the outlook of that immensely important body which we in Great Britain call foremen. These men are, in all countries, not only the leading craftsmen, but the very backbone of technical industry. No men are better worthy of that education which renders a man more useful not only as a craftsman, but as a human being able to influence his fellows. With a view to providing a base for the more intensive cultivation of the foreman, the Swiss Association of Machine Manufacturers and Metal Industries (including about 440 firms) has established, at Winterthur, the Werkmeisterschule des Arbeitgeberverband Schweizerischer Maschinen-Und Metal-Industrieller. At this school groups of foremen have the benefit of a thirteen weeks' course, during which they have the opportunity of getting to know not only each other, but each other's operational problems and activities. Apart from specific study, those attending the school visit representative works and throughout the course they are paid full wages plus living expenses. We do not find any reference to this admirable Werkmeisterschule in the list (Appendix I) given by Professor Edwards and Dr. La Roche. Indeed, in the face of an establishment of this kind it can hardly be correct to state that "greater value is placed upon rivalry than upon co-operation." Here, surely, is co-operation established at a level peculiarly valuable for those non-commissioned officers than whom there is no body more essential to the evolution of a sound national technical industry. This is a movement which can well be studied—as it is, indeed, being studied at the present time—by British technical industry.

We note that, in connection with research work generally, the authors of this essay quote certain views expressed by Dr. Friedrich Oederlin, of the firm of Sulzer Brothers. "It is our opinion," writes Dr. Oederlin, "that in the prosecution of research work the engineering industry should depend on its own initiative and, wherever possible, on its own financial resources, and not upon direct State aid, which can better be replaced by other forms of encouragement, such as the reduction of taxation on research undertakings. Purposeful and scientifically pursued industrial research is closely bound to the works which promotes it and cannot be separated from the manufacturing departments. It has always been courageous private enterprise which, in the free play of competitive forces, has produced the economically valuable triumphs of engineering." These are words which admirably express the convictions of experienced, honest and enlightened men in all industrial countries. An American research worker of rare discernment tells us that "the great testimony of history shows how often, in fact, the development of science has emerged in response to technological, and even economic needs, and how in the economy of social effort, science . . . pays for itself again and again in providing the basis for radically new technological developments. . . . The debt of science to technology is great. Even the most abstract researches owe their existence to things that have taken place quite outside science, and with the primary purpose of

altering and improving the conditions of man's life." Finally, it involves no disparagement of the value of research organisations if we remember that all research in engineering science should, in its interpretation and still more in its practical application, be strictly tempered by thorough workshop investigation as well as by the funded experience of the past. If a research organisation gets the upper hand and attempts to speculate in industrial design, the results may be harmful as well as unprofitable. The best research is that which leads most directly to solid practical results and the enthusiasm of research men (admirable in itself) must not be mistaken for the accurate intuitions of engineering science. Otherwise research, instead of being a good servant, may become an extravagant master.

Glass: A Handbook for Students and Technicians. Edited by J. HOME DICKSON. London: Hutchinson's Scientific and Technical Publications, Stratford Place, W.1. Price 25s.

THIS book gives an overall picture of the structure, composition, manufacture and application of glass. It has been written by technicians whose names are well known in the British glass industry. The editor does not claim that the treatment of the subject is exhaustive, but liberal use is made of photographs and documents. Operations in the manufacture of glass are quite difficult to photograph, but many of the illustrations are of considerable merit. Some of the sections fall into the error so often found in films, in which, for example, the same journey is made in different railway trains. In the book the series of photographs showing stages in optical glass manufacture is spoilt by the introduction of a final photograph showing a pot being broken down, whereas the more appropriate photograph showing the casting of optical glass is included in the dust cover of the book. At the end of each chapter, references are included for the purpose of convenience and as a guide to further reading, but the references are by no means comprehensive. Those on chemical glassware, for example, do not include the admirable pamphlet prepared by Professor Turner for bench glass workers.

A very useful idea is the incorporation of a glossary in the index. The authors do not, however, appear to have taken note of Professor Turner's research which establishes the correct spelling of the word "leer." These are, however, only minor criticisms of a book which is very well produced and will make a useful addition to the literature on glass. In Part 1 there is a survey of general principles covering the nature of glass, its chemical and physical properties. The principles of manufacture are dealt with in Part 2, special chapters being devoted to moulded and blown glass, flat glass and optical glass, including commercial glassware, safety glass, the use of glass in building, fibre glass, glass to metal seals and coloured glass, whilst there is an appendix devoted to spectral transmission of glass.

Unfortunately, there are some very conspicuous omissions from the book. For example, the British glass container industry produces every minute of the day and night throughout the year 6000 bottles and jars in a wide range of sizes and shapes, yet there is hardly any mention of bottles and jars in the book. Other sections of the glass industry have not been given the space and prominence which they deserve, even if considered only as contributions to the country's life and industry. The part of the book devoted to the applications of glass suffers from omissions, but it is perhaps unfair to expect that in the limited space available very adequate treatment could have been given to this immense subject.

It is hoped, however, that in the next edition a more comprehensive survey of the British glass industry's various sections may be included and that a little more research be undertaken to establish that the origins of glass go back to a date earlier than 2500 B.C.

Petroleum Geology. By E. N. TIRATSOO. London: Methuen and Co., Ltd., 36, Essex Street, W.C.2. Price 42s.

As a result of the rapid expansion of the petroleum industry over the last fifty or sixty years, the ever-widening field of petroleum geology now calls for almost complete specialisation in this subject as distinct from pure geology. In his preface the author of "Petroleum Geology" draws attention to the fact that more geologists are employed at the present time in the search for and development of petroleum than in any other branch of economic geology and that his book is designed chiefly for the student intending to take up this science as a career. At the same time, however, the book should be of use to the oilfield technician and the non-technical user.

In the field geological information is linked so closely with the practical oilfield problems of drilling and development that it is essential for the oilfield technician to understand the principles and application of the science. Similarly, so that the close liaison so desirable between the geologist and the field man shall be maintained, it is of great importance that the exploitation geologist shall know something of practical field problems. In his book the author has succeeded in compiling a clear and well-constructed text-book on this very broad subject and has also collected a vast amount of useful factual information.

The book can be divided into three main sections, viz., theoretical, factual and practical, presented in that order. The first section is devoted to the origin of petroleum and the processes by which it is accumulated. In this section a very complete comparison of the many theories on the former question is set forth clearly and with a well reasoned commentary. There follows an important chapter on the geological and geographical distribution of the world's oil, forming a suitable introduction to the second section, which gives a complete picture by continents of the world's oilfields, their characteristics and geological features, and includes statistical information on their production and the quality of the oil. The third section deals essentially with the work of the petroleum geologist in the field and much of the information in this section will provide a useful guide not only to the student but to the fully-fledged field man. After a description of the most common surface indications of petroleum comes a chapter on survey and mapping methods, which should prove of great use to the student. Included in this chapter is a highly informative though brief section on the comparatively new technique of aerial mapping.

The complex subject of geophysical methods of finding oil is dealt with in general principles only and, as the author points out, is intended as an introduction to the science. All geophysical methods at present known are, nevertheless, described and their relation to geological work emphasised. The last three chapters on exploitation geology, drilling mud and methods of correlation show a practical knowledge of field conditions too seldom seen in print and will be of particular value to the resident geologist and the field man.

Taking the book as a whole, it should provide an excellent text-book for the student; it should carry him through his scholastic training and be of value to him when he goes out into the field. It will, moreover, provide a useful and informative reference book to the oilfield technician.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

WEAR OF COINS

SIR,—I am wondering whether any of your metallurgist readers can explain why coins appear to wear in circulation at such widely varying rates.

There must be thousands of the Victoria "young head" pennies still passing from hand to hand, and if one examines a series of these issued during the twenty years from 1860, when the small coppers were introduced, to 1880, it will be found that they range in condition from examples which are completely illegible to others which are still cabinet specimens. If it be objected that twenty years is too long a time for comparison, it is quite possible to find specimens issued in the same year which vary nearly as widely.

The position with regard to silver is even more puzzling; silver coins of Victoria, Edward VII and George V issued before the first debasement of the coinage in 1920 are now scarce in ordinary circulation, but in those that are found the sixpences are generally the most worn, the shillings less so, and the florins and half-crowns are often what a numismatist would describe as "almost fine," yet on the face of it there seems no reason why small coins should wear more quickly than large ones, and this appears to be borne out by the fact that it is rare to find a worn silver threepenny piece.

Arising out of this, has any attempt ever been made to compute how many times a modern coin changes hand during its period of effective life?

W. J. CHAMBERS

London, W.14,
August 3rd.

THE FESTINIOG RAILWAY

SIR,—Efforts to save the world's first narrow-gauge public railway, the Festiniog Railway in North Wales, are now steadily gaining impetus.

On this famous railway steam locomotives were introduced for the first time on so narrow a gauge by C. E. Spooner. The fact that these locomotives still exist pays tribute to the designers and builders. On the Festiniog Railway bogie carriages were also introduced for the first time on British railways

The Minister of Transport refused the recent application by the company for a Warrant of Abandonment. At a meeting, convened by the Portmadoc U.D.C., of local authorities, local inhabitants and many railway enthusiasts it was resolved to oppose any further steps to abandon the railway.

The preliminary inspection of rolling stock took place in July, and it is proposed to hold a meeting in Birmingham some time this month.

The writer would be very pleased to hear from anybody interested, especially if they are in a position to help financially or professionally in the scheme.

LEONARD A. HEATH HUMPHRYS

31, Ashton Hill,
Corston, Bath, Somerset,
August 1st.

Auxiliary Vibrator for Hand and Machine Sieving

By T. H. HUGHES

MANY industries use sieves to determine the size characteristics of fine powders. This process is often laborious and time-consuming, particularly with powders which have a tendency to adhere to the sieve, or in which the dominant particle size is of the same order as the size of aperture in the sieve being used.

The fraction of the powder which is likely to adhere to the sieve usually consists of the superfine particles, which cause difficulty in the initial stages of sieving by choking the apertures. A similar effect is produced by "near-size" particles, which become lodged in the sieve. In both cases the apertures may be cleared by tapping the rim of the sieve, to impart a vibration to the mesh. When they have been cleared the rate at which sieving progresses depends largely upon the manner in which the powder is re-spread over the surface of the sieve.

Typical sieving machines perform these functions either by a combination of shaking and tapping, or by continuous vertical vibration. With hand sieving a skilled operator can re-spread the powder by shaking the sieve and at the same time clear the apertures by tapping.

At the request of a committee set up by the British Standards Institution to standardise sieving procedures, the Fuel Research Station carried out tests, using various methods of hand and machine sieving. In the course of this work it was found that the performance of sieving machines could be considerably improved, and the process of hand sieving simplified, by attaching an auxiliary vibrating device to the finest sieves.

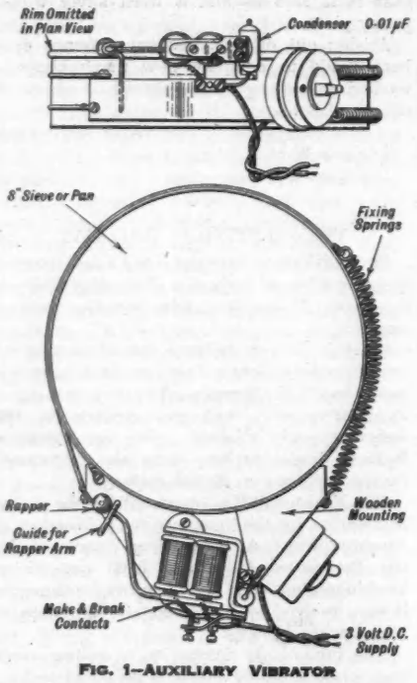

FIG. 1—AUXILIARY VIBRATOR

THE AUXILIARY VIBRATOR

As shown in Fig. 1, the device consists of a robust vibrator unit of an electric bell with a condenser connected across the contacts to act as a spark-quencher. The assembly is mounted on a wooden base, which may be attached either to the receiver pan or to any desired sieve in the nest, by two spring-loaded bands. Fig. 2 shows the arrangement as used for hand sieving with the apparatus fitted to the lower sieve of the nest. Figs. 3 and 4 illustrate its application to two typical examples of sieving machine.

PRELIMINARY SIEVING

Previous experience had shown that the duration of a sieving operation could be appreciably reduced if the superfine particles were first removed by sieving the powder for a period of five minutes on the finest sieve.

In order to determine the effect of the vibrator during this operation, tests were carried out with and without the device when sieving by hand and with two typical sieving machines, referred to in this report as type "R" and type "S," respectively.

FIG. 2—VIBRATOR FITTED TO SIEVE

The material used for the tests was a strongly-caking pulverised coal, which had been ground so that about 70 per cent passed through a 240 B.S. Test sieve. This material was selected, first, because it was known to be a difficult powder to sieve and, secondly, because its friable nature would accentuate any marked breakage of the particles due to vibration.

Sieving by hand was carried out according to a procedure recommended by Dr. H. Heywood, Chairman of the British Standards Institution Committee on Sieving Procedure. Following this method, the sieve was shaken whilst being rotated about its own axis with the mesh in a plane inclined at 30 deg. to the horizontal. It was tapped about six times with a small piece of wood at each 60 deg. interval of its rotation. A slightly modified procedure was adopted when using the vibrator for tapping the sieve; the surface of the mesh was not rotated about its own axis, but was inclined at an angle of 30 deg. to the horizontal and was made to follow the surface of an imaginary cone. Vibration was continuous.

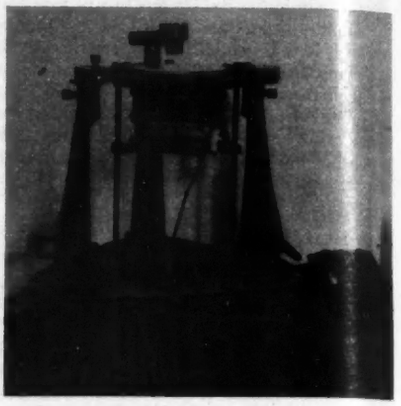

FIG. 3—VIBRATOR ON RECEIVER PAN OF TYPE "R" UNIT

The mechanism of the type "R" sieving machine causes the sieve to be shaken horizontally in an elliptical path at about 300 cycles per minute, whilst a rapper strikes the centre of the cover plate on the uppermost sieve about 160 times per minute. In the type "S" sieving machine a rapid vibration is imparted mechanically to the vertical axis of the sieve mounting at about 2000 cycles per minute.

A five-minute period was employed with each method of sieving. Table I shows the percentage of material which passed through a 240 B.S. Test sieve.

TABLE I—*Preliminary Removal of Fines*

	Percentage through 240 B.S. Test sieve	
	Without vibrator	With vibrator
Hand sieving	57·4	63·0
Sieving machine "R"	22·9	64·7
Sieving machine "S"	53·6	68·6

It will be observed from these results that in all cases the amount of fines passing the sieve is increased by using the vibrator. The difference is relatively small with hand sieving but considerably less skill and effort is required when it is used. On the other hand, the performance of the machines is improved from a standard well below that obtained by normal hand sieving to one appreciably above. It will also be seen that most of the fines are removed from the powder in five minutes by all three methods

TABLE II—*Effect of Vibrator on Final Sieving: Sieve Analyses*

Method of sieving		B.S. Test sieve, per cent					
		on 72	72–100	100–150	150–200	200–240	through 240
Hand sieving	Without vibrator	2·6	3·4	7·5	13·5	1·7	71·3
	With vibrator	2·2	3·8	7·8	13·7	1·8	70·7
Sieving machine type "R"	Without vibrator	2·2	3·7	7·8	13·4	1·7	71·2
	With vibrator	2·6	3·2	7·6	13·9	2·0	70·7
Sieving machine type "S"	Without vibrator	1·8	3·7	7·7	13·5	1·6	72·7
	With vibrator	2·3	3·4	7·4	13·5	1·7	71·7

TABLE III.—*Effect of Vibrator on Final Sieving: Times of Operation*

Method of sieving		B.S. Test sieve No.	Time, minutes			
			Main sieving	End point sieving	Cleaning sieves and weighing	Total
Hand sieving	Without vibrator	72	5	2	5	124
		100	10	4	10	
		150	15	4	10	
		200	25	6	15	
		240	40	8	20	
	With vibrator	72	10	4	10	136
		100	15	4	10	
		150	20	4	10	
		200	25	4	10	
		240	45	10	25	
Sieving machine type "R"	Without vibrator	72	10	4	10	136
		100	20	6	15	
		150	25	4	10	
		200	30	4	10	
		240	45	8	20	
	With vibrator	72	10	4	10	124
		100	20	6	15	
		150	25	4	10	
		200	30	4	10	
		240	40	6	15	
Sieving machine type "S"	Without vibrator	72	10	4	10	124
		100	20	6	15	
		150	30	6	15	
		200	35	4	10	
		240	40	4	10	
	With vibrator	72	10	4	10	112
		100	20	6	15	
		150	25	4	10	
		200	30	4	10	
		240	35	4	10	

TABLE IV.—*Effect of Vibrator on Overall Sieving Process: Sieve Analyses*

Method of sieving		B.S. Test sieve, per cent					
		on 72	72–100	100–150	150–200	200–240	through 240
Hand sieving	Without vibrator	2·6	3·4	7·5	13·5	1·7	71·3
	With vibrator	2·5	3·4	7·6	14·3	1·6	70·6
Sieving machine type "R"	Without vibrator	2·1	3·6	7·5	13·7	2·1	71·0
	With vibrator	2·1	3·5	7·4	14·0	2·9	70·1
Sieving machine type "S"	Without vibrator	1·5	3·0	6·9	13·3	2·9	72·4
	With vibrator	1·5	3·2	6·9	12·9	3·0	72·5

TABLE V.—*Effect of Vibrator on Overall Sieving Process: Times of Operation*

Method of sieving		B.S. Test sieve No.	Time, minutes			
			Main sieving	End point sieving	Cleaning sieves and weighing	Total
Hand sieving	Without vibrator	72	5	2	5	134
		100	10	4	10	
		150	15	4	10	
		200	25	6	15	
		240	45	8	25	
	With vibrator	72	10	4	10	146
		100	15	4	10	
		150	20	4	10	
		200	25	4	10	
		240	50	10	30	
Sieving machine type "R"	Without vibrator	72	10	4	10	202
		100	20	6	15	
		150	30	6	15	
		200	40	6	15	
		240	71	14	40	
	With vibrator	72	10	4	10	122
		100	20	6	15	
		150	25	4	10	
		200	30	4	10	
		240	40	4	15	
Sieving machine type "S"	Without vibrator	72	10	4	10	163
		100	25	8	20	
		150	50	10	25	
		200	50	2	5	
		240	60	4	15	
	With vibrator	72	10	4	10	122
		100	20	6	15	
		150	30	6	15	
		200	35	4	10	
		240	40	2	10	

of sieving when auxiliary vibration is employed.

FINAL SIEVING

In order to determine the effect of the vibrator during the final stages of a sieve analysis, the oversize material obtained by hand sieving the test powder in the normal manner for a period of five minutes on a 240 B.S. Test sieve was taken as a standard. A sieve analysis of this material was carried out on a range of five test sieves by the procedure described below.

The oversize material was placed on the uppermost sieve of the nest assembled in order of size, with the coarsest sieve on top. Sieving operations were carried out with the nest for successive periods of five minutes until the rate at which the material passed the top sieve had been reduced to a quantity defining the "end-point" for that sieve. It was considered that the end-point was reached when less than 0·2 per cent of the original sample passed through the sieve in two minutes of normal hand sieving. The uppermost sieve was then removed from the nest and the process repeated until all the sieves had reached their end-points in turn.

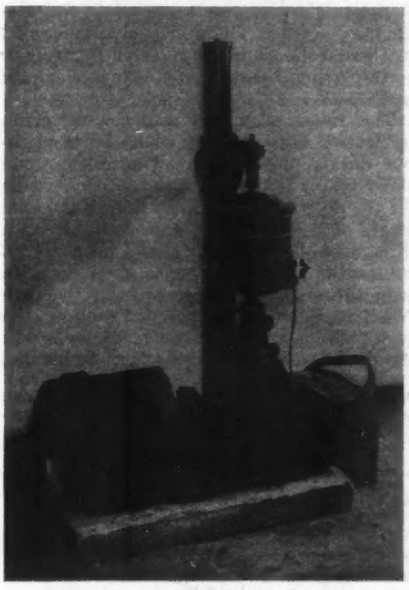

FIG. 4—VIBRATOR ON RECEIVER PAN OF TYPE "S" UNIT

The analyses obtained in this manner by the three methods of sieving are given in Table II.

It will be seen that there is no appreciable difference between the analyses obtained by the various methods of sieving, nor is there any evidence to show that the use of the vibrator has caused breakage of the particles.

Table III gives the time of sieving, the time taken to clean the sieves and weigh the residues, and the overall time of each test. In arriving at the overall time it should be noted that since the sieves are nested the total time taken in the main sieving process will be that for the finest sieve. For example, the total time of 124 minutes for normal hand sieving consists of forty minutes for main sieving with the sum of the times for end-point sieving and for cleaning and weighing.

Comparing these times, it will be seen that the time taken to complete the operation by hand sieving is 10 per cent longer with the vibrator than without. This

result is in apparent contradiction to the results for preliminary sieving, where its use increased the amount of material passing the 240 sieve in a five-minute period. It would appear that while the vibrator is effective in causing the fine particles to pass through the sieve, it is not so effective as the normal method of hand sieving in dealing with "near-size" particles.

A similar effect is observed with machine sieving. Although the overall time is reduced in each case, the difference resulting from the use of the vibrator during the final stages is small (about 10 per cent) compared with the large difference in the quantities passed with and without the apparatus during the preliminary sieving (Table I).

Overall Sieving Process

Further tests were carried out with and without the vibrator in use throughout the complete sieving process, including the preliminary sieving. The sieve analyses obtained in these tests are given in Table IV and the corresponding times for the complete sieving in Table V.

The times taken for hand sieving given in Table V show that the increased throughput during preliminary sieving when using the vibrator is not sufficient to compensate for the decrease in efficiency during the final stages of sieving. On the other hand, when it is used throughout on the machines, a substantial saving of time is effected. This is of the order of 40 per cent on the type "R" machine and of 25 per cent on the type "S" machine. It will be seen that the device is most effective in reducing the

Table VI—*Principal Results—Arranged in Order of Merit*

Preliminary sieving (5 minutes)	Per cent, through 240 B.S. Test sieve
Sieving machine type "S," with vibrator	68·6
Sieving machine type "R," with vibrator	64·7
Hand sieving, with vibrator	63·0
Hand sieving, without vibrator	57·4
Sieving machine type "S," without vibrator	53·6
Sieving machine type "R," without vibrator	22·9

Final sieving	Time of operation, minutes
Sieving machine type "S," with vibrator	112
Sieving machine type "R," with vibrator	124
Hand sieving, without vibrator	124
Sieving machine type "S," without vibrator	124
Sieving machine type "R," without vibrator	136
Hand sieving, with vibrator	136

Overall sieving process	Time of operation, minutes
Sieving machine type "S," with vibrator	122
Sieving machine type "R," with vibrator	122
Hand sieving, without vibrator	134
Hand sieving, with vibrator	146
Sieving machine type "S," without vibrator	163
Sieving machine type "R," without vibrator	202

times taken with the finest sieves and that it is gradually less effective with increase in aperture size of the sieve.

In Table VI the principal test results are presented together for purposes of comparison.

Conclusions

The auxiliary vibrator increases very considerably the rate at which the superfine particles, which normally tend to clog the apertures, will pass through a fine sieve. During tests with a sticky coal between 88 and 96 per cent of the fines passed through a 240 B.S. Test sieve in five minutes, compared with figures without the vibrator of 81 per cent with hand sieving and 32 and 75 per cent with two types of standard commercial sieving machine. The device is therefore a useful aid if the recommended procedure of carrying out a preliminary sieving of the original sample on a fine sieve is adopted.

As the size of the particles is increased the effect of the vibrator decreases and the vibrator has little effect with particles too large to pass through a 100 B.S. Test sieve. Hand sieving a powder from which most of the fines had been removed took 10 per cent longer with the vibrator than without, but with both machines the time taken to sieve the same powder was reduced by about 10 per cent.

Combining the two effects, it was found that the complete sieving operation took considerably less time when using the vibrator with either machine and slightly longer with hand sieving. Its use is therefore to be recommended for the complete sieving process, as it saves time with either machine. In the case of hand sieving it can be recommended as a means of reducing the degree of skill and amount of effort required from the operator.

When sieving a friable pulverised coal the results obtained with and without the vibrator were substantially the same with each method of sieving, showing that the vibrator did not cause degradation of the sample.

Acknowledgments

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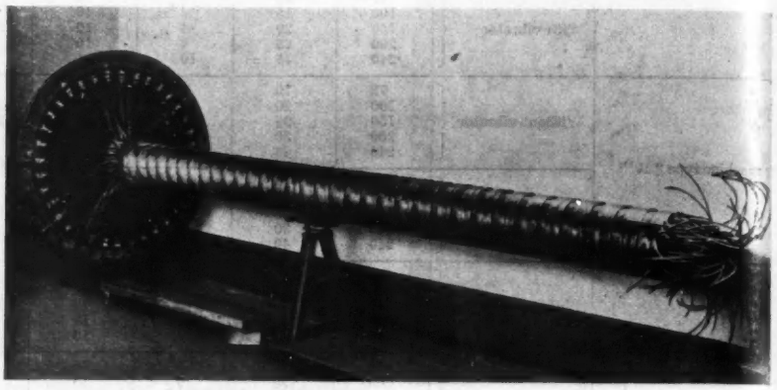
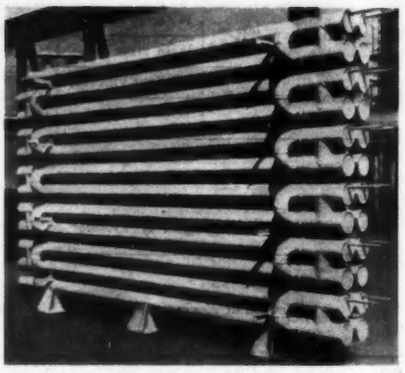
Special Heat Exchangers

There have been completed recently, at the Partington Industrial Estate works of Petrocarbon, Ltd., a range of high efficiency heat exchangers which have been designed for certain special purpose plants now under construction. Examples of the latest production are several cross counter current heat exchangers (one of which is shown under construction in our illustration) which are of special design and construction to meet the requirements of a Petrocarbon low pressure oxygen plant, which is expected to produce 200 cubic metres of pure oxygen per hour. The purpose of the heat exchanger is to effect an exchange of heat between air and nitrogen, the air passing through coiled tubes at a pressure of 75 lb per square inch and the nitrogen being contained within the shell at approximately atmospheric pressure. Within



Oxygen Plant Heat Exchanger

a diameter of 22¼in and an overall length of 20ft, the heat exchanger contains a total wound length of 34,680ft of ⅜in outside diameter by 20 gauge solid drawn copper tubing, which is worked in 289 separate lengths of jointless tubes, each 120ft in length. The tubing is wound on a core formed by a 7½in diameter tube, in such a manner that the total surface area available for the transfer of heat is some 3400 square feet. Each individual tube is



Refrigeration Plant Heat Exchanger

expanded into the end plates and then flooded with solder, and the shell, which is fabricated from copper sheet, is suitably jointed and mounted.

Another example of the company's production range is a bank of heat exchangers (shown in our photograph) built of mild steel and of all-welded construction. The equipment has been designed to form part of an ammonia absorption refrigeration plant to effect a heat transfer between strong and weak ammonia liquors, the respective speeds of flow of the liquors being 1600 gallons per hour on the tube side and 1800 gallons per hour on the shell side. The bank consists of twenty-four body tubes of 6in diameter, each containing twenty-six ⅜in outside diameter condenser tubes, which form a total effective heat exchange surface area of approximately 2000 square feet. Under working conditions, this area effects a heat transfer of 3,200,000 B.Th.U.s per hour. When erected the bank of exchangers is supported on three feet, there being an individual support, and separate pressure gauge connections, between each battery.

Generating Plant in Grudie Bridge Power Station

IN our issues of June 8th and 15th we published a description of the North of Scotland Hydro-Electric Board's Fannich scheme, including the Grudie Bridge power station. Further details of the generating plant installed there are given in the present article.

Very briefly, Grudie Bridge power station makes use of the storage capacity of Loch Fannich, which drains a catchment area of 55·2 square miles, where the average annual rainfall is 79in. At a later stage of the scheme a dam will be built across the eastern end of the loch to raise the water level by about 20ft and increase the storage capacity sufficiently to provide an additional output of about 4 million kWh. When the dam is completed the storage capacity will be equivalent to 83 per cent of the annual output of the station (83 million kWh) with a mean net head of 495ft.

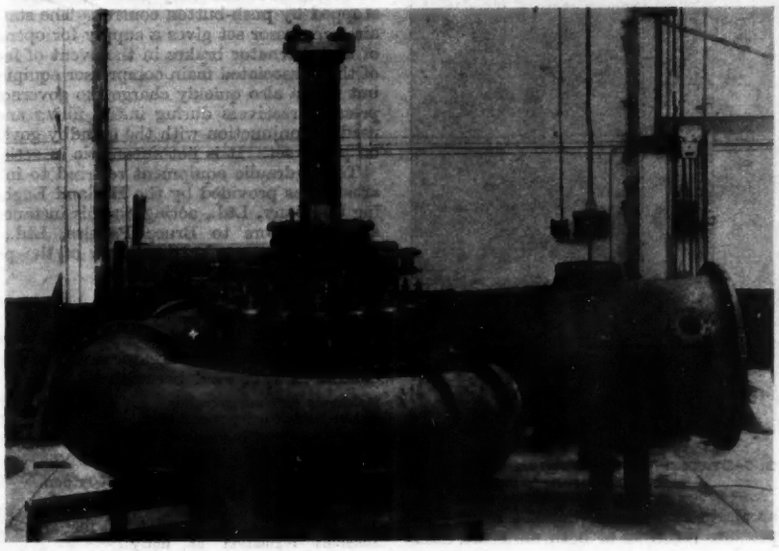


FIG. 1—TURBINE ERECTED AT MAKER'S WORKS

Grudie Bridge power station is connected to Loch Fannich by a tunnel 3½ miles long and having an equivalent diameter of 10ft. Near the mouth of the tunnel there is a surge shaft, 35ft in diameter and 210ft high. From there an 8ft diameter steel pipe-line about 1500ft long feeds the turbines after dividing into two 5ft diameter pipes immediately before the power station, which is built on two floors.

Control of the water at the power station is exercised by a 5ft diameter butterfly valve mounted on horizontal trunnions at the intake to each turbine. Each of these main shut-off valves is by-passed by an 8in diameter parallel-faced sluice valve for equalising the pressure before opening; the main valve is, however, capable of closing against full unbalanced pressure. Both main and by-pass valves are operated by hydraulic servo-motors using filtered water taken from the pipe-line. In each case the control valves are solenoid operated to allow controlled sequence operation by a single push button for opening and closing. In an emergency the main inlet valves may be closed from the alternator floor, 18ft above, using hand gear which directly actuates the pilot valves. The butterfly valve servo-motor water circuit includes a valve whose function is to retard the final closing of the main valve, thus eliminating water hammer. Main and by-pass valves are supplied with limit switches for electrical interlocking.

TURBINES AND PRESSURE REGULATORS

The two vertical shaft, single runner, Francis turbines are designed for operation over the normal range of net head, 458ft to 480ft and with a maximum gross head of 554ft. Each is guaranteed to produce 17,000 b.h.p. under 458ft net head, which is equivalent to the generator continuous maximum rating of 12MW. In practice, because of the general shortage of generating plant capacity in Britain, the turbines and alternators are regularly generating a total of 26MW, and one machine alone has delivered 14·7MW at the alternator terminals, which is equivalent to a turbine output of 20,400 b.h.p. an overload of 20 per cent.

The turbines are, as far as possible, of welded construction. In Fig. 1 we show one of the turbines during erection in the maker's works. The draught tube liners, spiral cases, curb rings, bottom plates, head covers, bearing housings, gate operating rings, connecting-rods, and pit liners were all fabricated and all parts subject to pressure were stress relieved. Each of the 14½in diameter Siemens-Martin forged steel shafts has a stainless steel sleeve where it passes through the packing box and is solidly coupled to a cast stainless steel runner. Bottom plates and head covers have renewable mild steel wearing plates presented to the top and bottom faces of the wicket gates, while the curb ring is provided with a renewable cast steel liner.

The cast steel wicket gates with integral spindles are connected through cast steel gate arms and cast iron links to the gate operating ring. The links were saw-cut, deliberately designed to break if any of the wicket gates should become jammed during a closing movement of the governor. In the linkage mechanism between a wicket gate and the gate operating ring there is an eccentric pin, which can be simply adjusted to take up wear between adjacent gates.

The main shaft bearings are flow lubricated from an external supply common to the turbines and alternators. Each bearing has a mercury-in-steel thermometer, whose dial is remotely positioned on a turbine panel situated on the alternator floor. The thermometer dial carries two adjustable maximum electrical contacts set at predetermined temperatures. One of the contacts is arranged to initiate an alarm system at one temperature and the other initiates shut-down of the machine at a higher temperature but before the danger point has been reached.

Differential pressure, which exists across a section of the spiral case, from the inner radius to the outer radius of the turbines, is used for measuring the quantity of water flowing through the turbine. The pressure differential is translated into quantity through the medium of a mercury column varying the resistance of an electric circuit feeding an indicating voltmeter reading directly in cusecs. In addition to the indicator there are flush-mounting, integrating and recording instruments, let into the face of a floor-mounted, sheet-steel cubicle at alternator floor level, which carries the instruments for both turbines, as shown in Fig. 2. The flow metering equipment has to be calibrated, using the results obtained during efficiency trials when the Allen salt velocity

FIG. 2—GENERATING ROOM

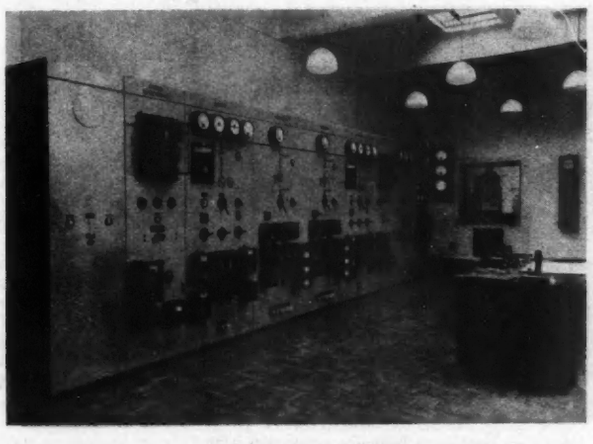


FIG. 3—MAIN CONTROL ROOM

method of measuring water quantity is used.

The pipe-line conditions are such as to require pressure regulators. When the load falls the pressure regulator associated with each turbine is actuated by a relatively fast closure of the turbine wicket gates, so that it opens to discharge water immediately and maintain, as far as possible, the velocity of the water column before the drop of load occurred. Closure of the pressure regulator takes place at a controlled rate, which reduces the effects of water hammer. The maximum rise in pressure which can occur due to a sudden rejection of load is 10 per cent. The control medium for the pressure regulators is clean, filtered water taken from the pipeline and the design is such that if the control water pressure is lost the regulators open and so fail to safety.

Automatic Governors

The speed of each turbine is controlled by a 42,000ft-lb automatic oil pressure governor, which is sensitive to a speed change of one-hundredth of 1 per cent. The speed measuring fly-balls are driven by a motor supplied from and running in synchronism with a permanent magnet generator direct coupled to the main alternator. Thus any change in speed of the generating set is instantaneously transmitted to the governor. The usual belt or mechanical gear drives are replaced simply by a small three-core electric cable. This simplification allows the governor to be sited in the best position commensurate with ease of control and access. The governor is so equipped as to run up its machine under its own control upon the pressing of a single push button. The mechanism accelerates the turbine evenly up to normal speed when the fly-balls take over control. Means are provided for securing the turbine wicket gates automatically when the machine is at a standstill and in the event of an oil pressure failure.

A motor-driven speeder device enables the speed of the machine to be varied by hand or remotely from minus 15 per cent to plus 5 per cent of normal speed for synchronising and loading purposes. The slow speed which can be obtained by this control is highly desirable as it ensures that the generating units can be synchronised at the low frequencies which now obtain during heavy electricity load demands. In addition to the speeder mechanism there is a speed droop (permanent speed variation) adjustment, which can be set at any value between zero and minus 5 per cent of normal speed, as dictated by parallel running conditions.

There is a manual load-limiting device, easily operated, which can be used for starting up and shutting down a machine under hand control, utilising the oil pressure. When no pressure oil is available the turbine may be controlled by handgear mechanically operating the turbine gates.

An accumulator is provided for storing the governor oil under pressure for each turbine. The compressed air cushion in the accumulator is generated by a gear type oil pump; there is no need, therefore, for a special high-pressure air compressor unit. When working pressure has been built up in the receiver, the oil pump unloads and returns its oil to the sump tank. The oil pump is driven by a 7½ h.p. squirrel-cage motor, which runs continuously. The pressure receivers (Fig. 2) are equipped with pressure switches having electrical contacts arranged to shut down the generating set and give an alarm at a predetermined low pressure. The pressure receivers of both units are interconnected.

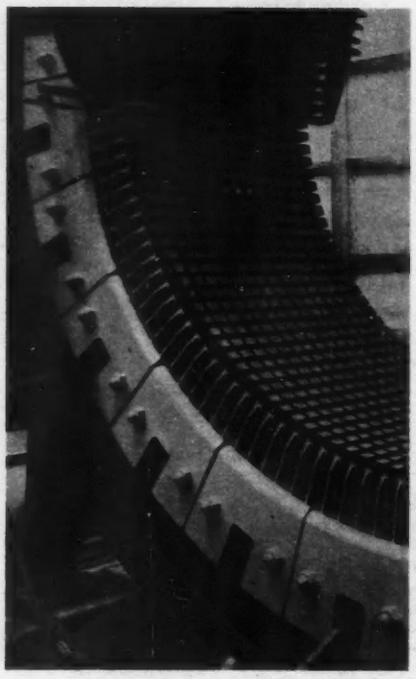


Fig. 5—Stator Core Showing Stepped End Sections

Each of the permanent magnet generators associated with the speed governing system contains self-resetting snap-action over-speed and under-speed mercury switches. The over-speed switch is set at 30 per cent above normal speed; the under-speed switch is interlocked in the alternator brakes circuit so that braking cannot be applied in the case of emergency shut-down until the speed of the unit reaches 95 per cent of normal. Additional arrangements are made so that, under normal conditions, the brakes cannot be applied until the speed falls to 50 per cent of normal.

Auxiliary Equipment

Three electrically-driven vertical shaft SDB5/6 "Uniglide" pump sets have been installed for circulating water for cooling the alternator air, lubricating oil and the oil for the OFW main transformers. One of these pump sets acts as a standby to be used in place of either one of the unit auxiliaries. Flow relays give alarm in the event of loss of cooling water supply to any one of the coolers.

As the draught tubes and pressure regulator outlets are below normal tailwater level, access to them can usually only be obtained by blocking off their outlets and pumping them dry. For this purpose an electrically-driven vertical shaft SWL(LL), 3in "Swallowglide" pump has been provided. This pump also supplements and acts as a standby to a float-switch controlled self-priming horizontal shaft pump set, which deals with station drainage water.

A horizontal shaft, impulse water turbine-driven standby governor oil pump and a standby compressor set are also provided. The standby oil pump is automatically brought into use in the event of governor oil pressure becoming low but may also be started and stopped by push-button control. The standby air compressor set gives a supply for operation of the alternator brakes in the event of failure of their associated main compressor equipment, but it can also quickly charge the governor oil pressure receivers during initial filling and be used in conjunction with the standby governor oil pump set. It is not automatic in action.

The hydraulic equipment referred to in this article was provided by the Harland Engineering Company, Ltd., acting, in this instance, as sub-contractors to Bruce Peebles, Ltd., the main contractors for the whole of the power station plant and transformers.

Generators

Each turbine is direct coupled to a vertical shaft Bruce Peebles generator designed for the conditions tabulated herewith:—

Maximum continuous rating ...	13·3MVA
Active load at 0·9 power factor	12·0MVA
Terminal voltage	11kV
Cycles per second	50
Phases	3
Speed	500 r.p.m.
Runaway speed	875 r.p.m.
Flywheel effect	490,000 lb ft²(WR^2)
Voltage tolerance	+10% and −15%
Inherent regulation at unity power factor	13%
Inherent regulation at 0·9 power factor	23%
Efficiency at rated output and 0·9 power factor	97·25%
Line charging capacity	6,667kVA zero leading p.f.
Total weight	94 tons

Photographs showing one of the generators under construction at the maker's works are reproduced in Figs. 4–6. The generators, in which fabricated construction has been used to the fullest extent, are totally enclosed machines with a closed system of ventilation, providing for recirculation of air within the housing, with cooling by six Serck water coolers disposed round the stator frame. The cooling air enters at both ends of the frame and is propelled by fans, fitted at both ends of the rotor, through the ventilating ducts to the back of the stator

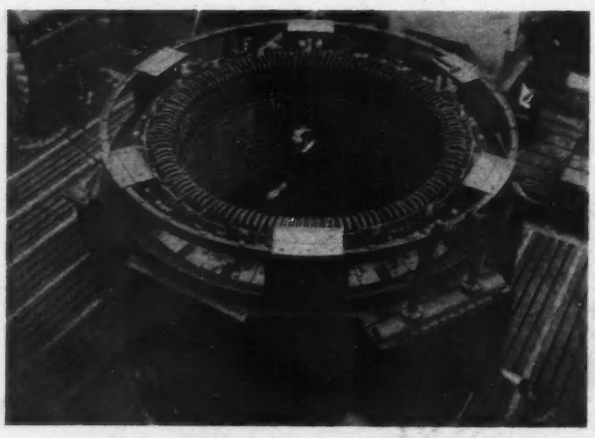


Fig. 4—Wound Stator with One Water Cooler in Position

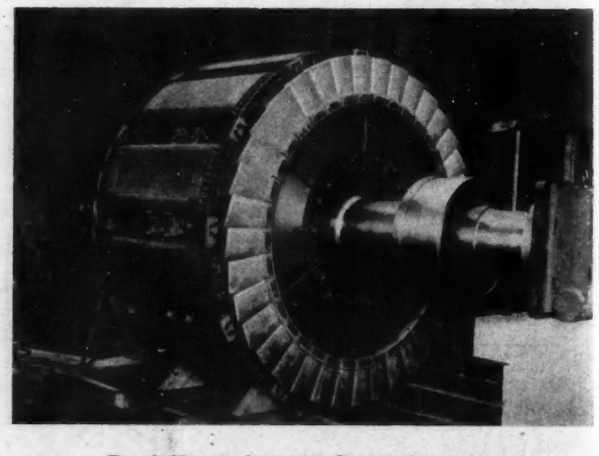


Fig. 6—Rotor Showing Brake Segments

and thence through the coolers before re-entering the housing. Hand-operated louvres allow the air circuit to be opened for heating the power station in cold weather, the make-up air being drawn in through Serck air filters. The generators are mounted on a plinth standing about 5½ft below the floor level, and their total height above floor level is 12ft 9½in.

The stator frames are fabricated from steel plate, built in two sections to facilitate transport. The core laminations are of low-loss silicon steel and part of the core assembly is shown in one of our illustrations. To reduce the magnetic flux density and local losses at the ends of the core a number of laminations in the end sections near the radial supporting fingers are stepped (Fig. 5) so as to increase the air gap gradually. The stator winding consists of diamond-wound coils laid in open slots, with Class B insulation. There are two circuits in parallel per phase and the winding is star connected. To minimise eddy current losses the conductor laminations are transposed throughout the winding. Individual conductors are covered with impregnated glass-tape and separated from each other with mica. The slot portions of each coil are moulded with micafolium ironed-on hot, and the ends of the wrap, which are tapered off, are sealed with mica tape. The top and bottom coils in the slot are spaced apart with leatheroid. Coils are braced where they leave the slots by varnish-impregnated wooden blocks bandaged to the coils, and the end windings are secured to insulated continuous steel bracing rings supported by brackets bolted to the stator end plates, as shown in Fig. 4. Embedded temperature detectors are provided for use with a dial type thermometer, now normal for plant of this size.

In the rotor assembly shown in Fig. 6 the body is built up from nine rolled steel plates machined all over, shrunk on to the shaft, and secured by transverse bolts. Dovetailed grooves are machined in the assembly into which the poles, built up of dovetailed laminations clamped between rounded steel end plates by fitted bolts, are pressed and keyed without undue stressing of the material. The rotor coils consist of copper strip wound on edge, insulated between turns with asbestos and mounted on flanged brass spools with Bakelite washers at top and bottom. The coils are insulated from the spools by glass cloth and micanite, reinforced with leatheroid. They are mutually braced by bronze vee-shaped clamps bolted to the rotor body, the connections also being braced, to withstand the action of centrifugal force at overspeed. A damper winding is provided on the periphery of the poles to damp out any oscillations which may occur during disturbances on the line. The underside of the rotor is fitted with six renewable machine-finished Meehanite cast iron brake segments (Fig. 6), secured by spring-loaded bolts to provide for thermal expansion without buckling. Propeller type fans are fitted to both ends of the rotor.

The thrust bearing and upper guide bearing are mounted above the rotor, forming a single enclosed unit which is carried on a fabricated steel radial-arm bracket. The Michell thrust bearing is designed for a loading of 85 tons. Both thrust and upper guide bearings are insulated to prevent shaft currents. A second guide bearing is fitted below the rotor and is carried on two transverse beams, which can be removed to allow the housing to be lowered by a tackle for inspection and to give access to the brakes and jacking gear.

All bearings are flow lubricated from an overhead distributing box fed from a 400-gallon reservoir at 8 lb per square inch, control feeds descending to the thrust bearings, top and bottom guide bearings, and turbine bearings respectively. They are fitted with mercury-in-steel thermometers with elements connected to dials on the turbine panel. To give audible alarm and visual indication of an abnormal bearing temperature each thermometer dial carries two adjustable contacts, the first to initiate an alarm at a predetermined temperature and the other to operate at a higher temperature to shut down the machine before the danger point has been reached. Oil flow indicators are provided, arranged with contacts to operate should the circulation fail for any reason.

The braking gear, which is carried on the bottom bearing bracket, as illustrated in Fig. 7, consists of four Tangye cylindrical hydraulic jacks fitted with Ferodo pads. In operation, compressed air at a pressure of 8 lb per square inch is admitted to the oil reservoir; for jacking oil is pumped in by hand at 1000 lb per square inch, the weight then being transferred to the six screw jacks seen in the illustration.

Each generator has a main and a pilot exciter, which are mounted one above the other on top of the thrust bearing bracket and are direct coupled to the main generator shaft. All the electrically driven auxiliaries are supplied at 415V by 50kVA transformers, the primaries of which are connected to the 11kV terminals of the generators and the secondaries to the unit auxiliary boards. Normally the starters for the auxiliaries are latched in so that they run up to speed with the generating set they serve. Other electrically-driven auxiliaries are supplied from a common services board, which can also be energised from either of the two 250kVA earthing transformers associated with the main 60MVA transformers or from a 3MVA, 33/0·415/11kV linking

FIG. 7—BOTTOM BEARING BRACKET AND BRAKE GEAR

transformer serving a local 33kV line from Beauly. Selection of one of these transformers is made automatically in a predetermined sequence at a selector panel, which also provides for the switching of one to the other in the event of the failure of any one transformer. The unit auxiliary boards and common services boards can be connected with one or other of the generators or can be supplied independently from the main transformers, which are direct connected to the 132kV line from Beauly substation, for testing the auxiliaries when the turbines are shut down. A d.c. supply at 240V is available from a battery for standby auxiliaries and control circuits, and at 50V for alarms and telephones. Battery charging rectifiers are provided, which receive their supply from the 415V common services board.

TRANSFORMERS

The two generators are connected through circuit breakers to the 11kV busbars, from which the supply is taken to two 20MVA, 11/132kV, delta/star connected outdoor, oil-immersed, water-cooled transformers, which are mounted on a concrete raft at the back of the power station, immediately above the bifurcated pipe-line.

The transformers are of the conventional core type with windings formed of disc coils arranged to minimise mechanical stresses under short-circuit conditions. To withstand the severe stresses that may be expected under severe impulse conditions due to lightning the arrangement of coils and insulation, both between turns and sections, is graded to give maximum electric strength. One limb of the h.t. winding is reversed so as to reduce the electric stress between phases, and the h.t. winding has been subjected to an impulse test of 640kV.

The transformers are equipped with duplicate forced-oil cooling, the coolers, with their electrically-driven oil pumps, being mounted on one end of the tanks. Auxiliary natural cooling is provided by a small bank of radiators mounted on the opposite end of the tanks to deal with no-load losses only. The forced oil cooling system is duplicated to provide 100 per cent standby facilities. Each pump is capable of dealing with full-load cooling requirements by forcing oil through one or other of the Serck coolers. In these coolers the oil passes along a nest of small-bore tubes mounted in a jacket, through which water is circulated to dissipate the heat from the oil. A duplex valve is fitted to allow either pump or cooler to be used. Failure of a pump results automatically in immediate change-over to the standby pumping set; simultaneously an alarm signal is operated in the power station. As an additional safeguard flow alarms are fitted to both oil and water pipes. These alarms incorporate auxiliary contacts which will bring the transformer out of the circuit in the event of a potentially dangerous condition. Oil pressure regulators are provided on the outlet side of the coolers to ensure that the pressure of the oil is always above that of the water.

Temperature indicators are provided, designed to simulate the temperature condition of the windings. They comprise a dial thermometer, with maximum and minimum contacts and alarm contacts, the mercury bulb of which is immersed in the oil of the transformer. The bulb is embedded in a resistance winding which is fed from a current transformer mounted over one of the l.t. main leads. The apparatus operates in conjunction with mercury switches and relays arranged to give an alarm signal and to cut out the transformer at a predetermined bulb temperature. The units are also provided with Buchholz protection, and are earthed by means of 250kVA, 11,000/415V earthing transformers which also give a low voltage supply to the station. Each main transformer weighs 73 tons (62 tons stripped for transport).

STATION CONTROL

Grudie Bridge power station is the first of a group of six generating stations in the Conon Basin, the whole forming a project which, when completed, will have an installed capacity of 107MW. Ultimately remote control of these stations is visualised from a supervising centre at Contin, but at present there are three methods of control available at Grudie Bridge: manual control, push-button control from centralised push-button stations, and semi-automatic control from a single push button which initiates the complete sequence of functions necessary to bring the plant to the "ready to synchronise" condition. Attendance on the plant and supervision of the generators are in the hands of the power station staff. While the first two systems of control follow general hydro station practice, a more detailed description of the semi-automatic control employed may be of some interest. For starting and stopping the plant a sequential-parallel method of control has been adopted. This system provides for the slower preliminary operations in starting the machines to be carried out simultaneously to minimise the overall starting time. When the starting impulse is issued a master contactor is operated, which energises and simultaneously starts the standby turbine-driven governor oil pump and d.c. motor-driven bearing oil pumps (supplied from the station battery) and opens the solenoid-operated by-pass valve. As soon as the spiral casing has filled and the pressure across the main shut-off valve has equalised, the solenoid-operated main valve opens, latching in the by-pass valve, which is de-energised and shut immediately the main valve is fully open. Not until the various relays indicate that (*a*) the pressure of the governor oil has reached the correct figure, (*b*) the turbine main valve is open, (*c*) circulation of oil to bearings is established, (*d*) the brakes are off and jacks lowered, is the governor solenoid energised to open the guide vanes and allow the turbine to run up to

speed under control of the governor. As the voltage in the direct-connected unit transformer increases, the essential main a.c. motor-driven auxiliaries (governor oil, bearing oil, and circulating water pumps, the starters of which are latched-in and normally closed) run up in unison with the turbine, and automatically take over the loads of the standby pumps, which then shut down. When all functions have been properly established, as indicated by the various relays, a signal is given that the set is ready for synchronising. It is then operated entirely from the control room (Fig. 3) through switches controlling the governor speeder motor, motor-operated generator field rheostat, and automatic voltage regulator, and is switched on to the network through oil circuit breakers. If for any reason the starting sequence should fail at any point the starting-up operation is cancelled and the nature of the defect is indicated on the alarm panel by means of a flashing light. The standby turbine-driven governor oil pump already mentioned delivers oil into a bus pipe to which the main pumps are also connected, and is automatically re-started in the event of the pressure in the bus pipe falling below a certain value.

Upon the stop impulse being issued (the generator being first relieved of load and the oil circuit breaker opened), the governor solenoid is de-energised, causing the turbine gates to close. The turbine valve-closing solenoid is then energised, latching-out the pilot valve and de-energising itself. The butterfly valve is thus made to close. If the valve should for some reason fail to close, the alarm system comes into operation. When the speed has dropped to about 50 per cent a relay operates and oil is supplied to the brake shoes, which stop the set. After a time lag sufficient to ensure that the turbine has come to rest, the brake shoes are again released automatically. The essential auxiliaries automatically shut down with the main plant and, when the bearing oil pressure falls below a certain value, the standby bearing oil pump runs up, shutting down again after a time sufficient to ensure that the turbine has stopped.

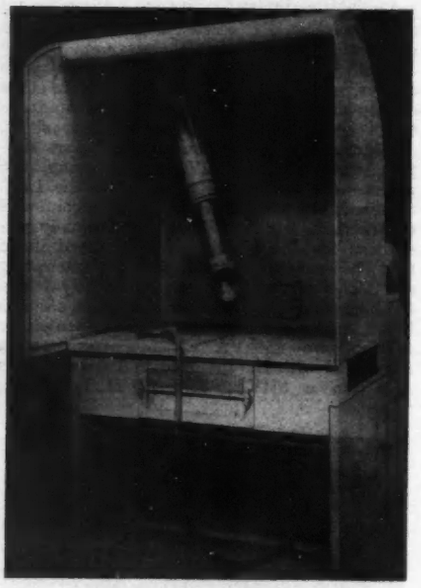
Arrangements to protect the plant under various fault conditions are embodied in the control scheme. The incidence of any of these fault conditions, some of which have already been mentioned above, lights an illuminated signal designating the fault, and operates audible alarms and a flashing beacon lamp. Briefly, the protective devices have the following effect. The circuit breaker is opened and the set stopped in the event of an internal fault in the generator (Merz Price protection), overcurrent or over-voltage, over-speed, low governor oil pressure or abnormal bearing temperature. The oil circuit breaker controlling the transformer is opened in the event of internal faults (Buchholz protection), overload, failure of water coolers, failure of both oil pump motors.

A list of the contractors responsible for various aspects of the Fannich project, including Grudie Bridge power station itself, was given on page 783 of our issue dated June 15, 1951.

Magnesium Alloy Dust Collector

THE present rearmament programme again calls for the extensive use of magnesium alloys, and the problem of collecting dust from machining operations is of the utmost importance, as magnesium alloy dusts are explosive and inflammable under certain conditions. Consequently each flexible shaft grinding or polishing machine must have its own separate collection unit to comply with the safety precautions laid down by the Factories Act. The plant which we illustrate is one made by Dallow, Lambert and Co., Ltd., Leicester.

In this plant the dust is collected and thoroughly immersed and scrubbed in a water chamber, the dust-laden air being passed through three water submersions. Should the velocity of air flow in the extraction ducts fall below the requisite speed, an automatic device stops the grinding or polishing machine, which cannot be re-started until the air flow is restored. A similar safeguard applies to the water level should it fall, due to evaporation or any other reason, below the set level for efficient scrubbing of the dust. In further compliance with safety requirements a time switch is incorporated to ensure that the unit fan runs for a period of five minutes so that any latent gases which may



MAGNESIUM DUST COLLECTOR

have accumulated, perhaps overnight, are cleared before the grinding or polishing machine is started up. Explosion releases are also fitted to the equipment.

The illustrated model is provided with a booth, which contains a telescopic universal fitting. A suitable air velocity is maintained within the booth, and the universal fitting can be moved by the operator to any desired position.

Barrow Iron and Steel Works

THE Iron and Steel Corporation of Great Britain states that it has agreed to take over the Barrow Iron and Steel Works from the Ministry of Supply. The United Steel Companies, Ltd., a publicly-owned company, will continue to manage the works as it has done for the Ministry of Supply. The hoop mills are being modernised and improved at a cost of £150,000 and these mills are believed to have good prospects. A further £60,000 is being spent on an experimental pilot plant to be installed to try out a new process for continuous casting of steel billets for the hoop mills. The Corporation says that steel production is expected to be limited to that required to feed the hoop mills and, owing to the raw materials shortage, two out of seven open-hearth furnaces may be shut down shortly. Consequently some workers may be permanently displaced during the next few months. According to the Corporation, there are a number of vacancies for men in the Barrow area, and it is hoped that jobs will be found for all the employees who are stood off. The United Steel Companies, Ltd., is discussing with the trade unions the timing and application of the change.

ALLOY AND STAINLESS STEEL SCRAP.—The Minister of Supply has made a new Order which provides maximum prices for scrap alloy steel, from August 1st. It is entitled the Iron and Steel Scrap (No. 3) Order, 1951, and reimposes price control on the main specifications of alloy steel scrap. It also brings all the important specifications of stainless steel scrap under statutory price control for the first time.

French Engineering News

(From our French Correspondent)

The first of three new cargo ships designed along new lines has just entered service. It is the motor-ship "Marie-Therese Le Borgne," and has a displacement of just over 1000 tons and a speed of 14 knots. Tests have shown that the new ship is extremely smooth sailing, even in rough seas. It is expected that the vessel will be used as a prototype for future construction.

* * *

The Société de Construction de Chassis has constructed a trailer, to carry 100 tons, which can be used either for road or rail transport. The chassis comprises two dropped frames rising at the ends in "swan necks," and the distance between the frames carrying the load can be widened from 2·40m to 3·30m.

The fabricated steel bogies are each carried by six half-axles fitted with pneumatic tyres. The rear bogie is controlled automatically and can be steered through a servo-motor controlled by the driver. Westinghouse pneumatic brakes are used.

The bogies for running on the railway are similar to those used for the road. Without the tractor, the road trailer is 21·60m long. The tractor used for hauling the trailer is of 270 h.p. and has a speed, when loaded, of 22km per hour on a straight road.

* * *

New methods for detecting faults in telephone cables have been tried out by the French Post Office. Instead of pumping compressed air into the cable and watching for a reduction in pressure to indicate the break, radio-active methyl bromide is injected, thus causing the cable and the ground through which it runs to become radio-active. A Geiger counter is then used to indicate the exact place where the cable is broken.

* * *

Monsieur Constant, president of the Association of Steel Products Users, recently commented on the French steel situation. He said that steel production was, on the whole, quite satisfactory. The domestic market, he maintained, had sufficient steel for the time being and there was a surplus for export. The coke shortage was not to be taken too seriously, he added. The Minister of Commerce and Industry had warned the country that shortage would limit production to 85 or 90 per cent, continued Monsieur Constant, but it should be remembered that he meant 90 per cent of maximum capacity. He admitted that shortage of coke and scrap would limit steel production, but pointed out that this was not peculiar to France, and said that the whole of Western Europe was suffering from the same trouble.

On behalf of all the steel users in France, Monsieur Constant suggested that they should be given priority over export, that export licences should only be granted after they had been carefully examined, that the steel industry should agree to fix firm delivery dates, and that the whole price structure should be studied in relation to the price of steel in other countries.

* * *

It is reported that some of the steel users in France have complained that certain steel delivered to shipbuilders, the railways and Government engineering services is not of the same quality as that delivered to private steel users. The Association of Steel Users has asked that the number of different kinds of steel should be reduced, and has announced that a technical committee on which every class of steel user will be represented has been set up to study the question and make recommendations.

* * *

A conference between French and Spanish engineers to study the building of a dam at Moulouya has recently taken place. A Franco-Spanish civil engineering organisation will be set up to carry out the work. The reservoir will hold 1000 million cubic metres of water and the work will last two years.

Industrial and Labour Notes

Railway Wages

It was announced last week that the three railway unions—the National Union of Railwaymen, the Associated Society of Locomotive Engineers and Firemen, and the Transport Salaried Staffs Association—had put forward a joint claim for a 10 per cent increase in wages for railway workers. The claim has been submitted to the Railway Executive and to the other executives of the British Transport Commission employing members of those unions. Over 500,000 workers are reported to be affected by the claim.

This is the first occasion on which the three railway unions have formulated a joint demand, although it will be remembered that, following the rejection of their individual claims last year, the Railway Executive finally granted, in February, a general wage increase amounting to about 7½ per cent. The demands made then by the N.U.R. and the A.S.L.E.F. were in excess of that amount. In addition to the joint claim, the A.S.L.E.F. is now asking higher rates for Saturday afternoon and Sunday work on the ground that additional payment for weekends is essential to maintain adequate train services. A statement on the new claim, made by Mr. Figgins, general secretary of the N.U.R., said that the railway staff situation would continue to deteriorate where the wages and salaries were not brought into line with those of outside industry.

The last railway wage increase, granted in February but made retrospective to January 1st, is estimated to have added £12,000,000 a year to the railway wages bill. In April, freight charges were increased and the British Transport Commission has since prepared a scheme for increasing passenger charges. When the February award was made the union representatives expressed their readiness to co-operate fully with the Railway Executive to increase efficiency and improve productivity in the railway industry. To that end a joint committee was set up, which is stated to have held several meetings. So far, however, the only outcome of the committee's deliberations has been the decision to discontinue the practice of employing callers-up to call footplate men and guards for rostered turns of duty.

The Industrial Disputes Order

The Minister of Labour has made the Industrial Disputes Order, 1951, which revokes the Conditions of Employment and National Arbitration Order, 1940. The new Order makes provision for an Industrial Disputes Tribunal to decide any disputes reported to the Minister of Labour, which cannot be settled by existing negotiating machinery. But only employers' organisations, individual employers or trade unions as defined by the Trade Unions Act of 1913 have the right to report disputes, which must concern terms of employment or conditions of labour. The Order stipulates that "the award of the Tribunal shall become an implied term of the contract between the parties." It excludes those provisions in the revoked Order which prohibit strikes and lockouts.

Before the House of Commons rose for the summer recess on August 2nd, the Minister of Labour, Mr. Robens, stated that the Industrial Disputes Order would operate from August 14th. It had been framed, he said, after full discussion with the British Employers' Confederation, the General Council of the Trades Union Congress and representatives of the nationalised industries. Although the Order contained no provision prohibiting strikes and lockouts, the Minister would have discretion to refuse access to the Tribunal where action was being taken resulting in a stoppage of work or in a substantial breach of agreement between the parties. Mr. Robens added that such matters as the employment or non-employment of a worker and claims for reinstatement were excluded from the Order, as experience had shown that such matters were not susceptible to settlement by compulsory arbitration.

The F.B.I. and the Economic Situation

In a memorandum issued at the end of last week, the Federation of British Industries has commented on the "grave turn in the economic situation" disclosed by the latest statement in Parliament of the Chancellor of the Exchequer. The Government's proposals to meet this situation, the memorandum says, make no attempt to remove the root causes.

The F.B.I. emphasises once more that higher productivity requires greater effort from all, an adequate supply of materials, and the requisite capital equipment and services. Whilst, the memorandum points out, a considerable advance in productivity has been made in the manufacturing field, substantial improvements are still to be obtained even though the result in the short term may be affected by insufficiency of some materials and the dislocation caused through switching over to production for defence. Outside the manufacturing field, it is added, there is ample scope for greater productivity, notably in higher output of coal, more efficient operation of transport and quicker turnround of shipping. The promotion of higher productivity, the memorandum declares, depends on incentives and flexibility. Effort, ingenuity and courage in production and development must be stimulated and not frustrated.

The Federation then comments on prices and profits and the limitation of dividends, saying that profit is a very small element in price, but is nevertheless an essential factor in the maintenance of industry. It is mainly the source from which funds have to be found for the greatly increased working capital necessitated by the rise in price levels and to finance the modernisation and development which are essential to the preservation of efficiency, the increase of productivity and the maintenance of operations. Over half the profit earned, the memorandum remarks, is drained away by taxation, and after providing for the requirements mentioned, the proportion distributed as the reward of the owner of the capital who has risked it in the venture is very small. As a direct means of reducing purchasing power and inflationary pressure, the limitation of dividends is admitted on all sides to be insignificant. The total amount of purchasing power represented by distributed profits is a small proportion of the total income of the people, and the amount represented by recent increases is negligible. Distributed profits, the Federation states, judged by any reasonable standard, have shown a far lesser increase than almost any other form of income, and the very people who for some years voluntarily observed restraint are now to be penalised.

The memorandum concludes by saying that industry is already seriously perturbed about the ability to provide the capital to maintain operations because of the heavy burden of current taxation. The introduction of legislation which will inevitably create difficulties in the raising of new capital will make that situation more grave. Moreover, it is claimed, the proposed dividend legislation is bound to influence British capital to seek an outlet overseas, militate against the investment of foreign capital in this country, and shake confidence abroad in our financial stability.

Iron and Steel Consumers' Council

The Minister of Supply announced last week the membership of the Iron and Steel Consumers' Council, which has been set up under the Iron and Steel Act, 1949, to consider any matter, including prices, affecting the interests of steel consumers. Sir William Palmer is the independent chairman of the Council, the other members being Sir Amos Ayre, Mr. Ralph Bennett, Mr. A. L. Shuttleworth, Sir Andrew McTaggart, Mr. C. M. Spielman, Mr. Robert Arbuthnott, Mr. W. Moray Lines, Mr. W. D. Wilson, Sir Harry Railing, and Mr. R. G. D. Ryder (representing the iron and steel consuming industries); Mr. M. C. Wade, Mr. J. W. Annetts, and Mr. H. Basil Darby (representing iron and steel merchants and stockholders); Mr. W. B. Beard, Mr. J. Tanner and Mr. F. Hayday (representing workers in the consuming industries); and Sir John Hacking and Sir Daril Watson (representing the nationalised industries). The Iron and Steel Corporation of Great Britain has nominated two of its members, Sir John Green and Mr. W. H. Stokes, to serve on the Council.

The Council may consider questions concerning any of the principal products of the publicly-owned section of the iron and steel industry and will report its conclusions to the Iron and Steel Corporation. In particular, the Council must consider matters arising from representations by consumers or referred to it by the Minister of Supply or the Corporation. Furthermore, it must consider any representations made to it by persons who have applied to the Minister of Supply, under Section 29 of the Act, for a licence to carry on iron ore mining and smelting, or the production or hot rolling of steel. It is stated that, after consultation with the appropriate organisations, the Minister of Supply has decided that the private section of the iron and steel industry shall not at present be represented on the Consumers' Council. That section's organisations will continue to discuss problems of common interest directly with the Iron and Steel Corporation. The offices of the Consumers' Council are at 1, Chester Street, London, S.W.1.

Iron and Steel Statistics

The British Iron and Steel Federation has just published Part I of its Statistical Year Book for 1950, which contains a very comprehensive set of figures relating to all aspects of the United Kingdom's iron and steel industry. In addition to iron and steel production, finished steel deliveries and the use of raw materials, the tables included in the volume give details regarding imports and exports, prices, stocks, and employment in the industry. They have been conveniently grouped according to subject, beginning with iron ore and working through the various sections of the industry to overseas trade statistics.

Two summary tables, giving information for a long run of years, will be especially useful at the present juncture of the iron and steel industry of this country. The first brings together the main statistical series relating to iron ore, coke, pig iron, scrap and steel, and the second sums up the information about the supply and disposal of steel. This latter table shows, for example, that the total steel supply, including imports, increased from an annual average of 8,370,000 tons in the years 1921 to 1925 to 11,220,000 tons in 1938 and to 17,430,000 tons last year. Over the same period of years home deliveries of steel advanced from 5,050,000 tons to 14,180,000 tons.

The Federation has also issued this week Part II of its Statistical Year Book for 1949. This is a document which gives detailed statistics for all the steel-producing and the most important steel-consuming countries of the world, thirty-five in all. In addition, it includes three tables showing, respectively, the world production of iron ore, pig iron and steel by country for a long period of years.

Both volumes are obtainable from the offices of the Federation, Steel House, Tothill Street, London, S.W.1. The price of the first is 7s. 6d. and of the second 15s.

Notes and Memoranda

Rail and Road

THIRD-CLASS SLEEPING CARS.—Twenty-one third-class sleeping cars of new design are being built for British Railways. These cars will have two berths in each compartment instead of the four as now. The new cars will be of two different kinds; one will have eleven compartments and an attendants' section and the other twelve compartments. Each compartment will contain an upper and a lower sleeping berth fitted with a well-sprung mattress and will be complete with pillows, blankets and sheets. There will be a wash-basin with hot and cold running water in each compartment and two toilets in each coach.

BRITISH RAILWAYS' IMPROVEMENT SCHEMES.—More than 150 large schemes for improving freight traffic working are now in progress on British Railways, or have recently been authorised. These schemes include the construction of a new railway, 7 miles long, to serve colliery development in Nottinghamshire; a series of new facilities to meet the development of the Fifeshire coalfield, and the modernisation and enlargement of seven goods stations and warehouses. Progress is also being made in the restoration of many passenger stations and in the modernisation of signalling equipment on important sections of line, to enable traffic to be worked with greater safety and expedition.

Air and Water

RECORD OCEAN SOUNDING.—The Danish Research ship "Galathea," which is a naval frigate of 1300 tons, is at present in the Pacific Ocean. Using a M.S.21.K Kelvin Hughes echo sounder, a record depth of 10,500m at the Mindanao Trench in the Phillipine deeps has been measured.

Miscellanea

OFFICE MACHINERY EXPORTS.—The Office Appliance and Business Equipment Trades Association has stated that in the first six months of this year exports of office machinery from this country reached a total value of £4,140,747, compared with £2,708,029 in the corresponding period of 1950, and £3,935,951 in the whole of 1949.

AMERICAN PRODUCTIVITY TEAM.—At the conclusion of its tour of Great Britain the American Sheet Metal Productivity Team, lead by Mr. F. C. Greenhill, paid a visit to the exhibition, "The First Century of Aluminium," arranged by the Aluminium Development Association, and showed particular interest in the display of aluminium motor-coachwork pressings.

FLOODLIGHTING THE FESTIVAL GARDENS.—One of the features of the Festival Gardens in Battersea Park, London, is the effective floodlighting of the walk and surroundings with 140W sodium floods. Many of the projectors have been mounted in the trees themselves and the result shows the versatility of the projectors employed. The installation was carried out by Barlow and Young, Ltd., and Drake and Gorham, Ltd.

THE WORLD POWER CONFERENCE.—At the recent annual meeting of the British National Committee of the World Power Conference, Dr. A. Parker, Director of the Fuel Research Station, was elected honorary secretary. Sir Vincent de Ferranti is chairman of the committee, Mr. Harold Hobson vice-chairman, and Colonel C. M. Croft honorary treasurer. The offices of the committee are at 201–2, Grand Buildings, Trafalgar Square, London, W.C.2.

EASINGTON COLLIERY EXPLOSION INQUIRY.—The Minister of Fuel and Power announces that he has appointed Mr. H. C. W. Roberts, C.B.E., H.M. Chief Inspector of Mines, to hold the inquiry into the explosion which occurred at Easington Colliery, County Durham, on May 29th, in place of Sir Andrew Bryan, who relinquished the post of Chief Inspector on his appointment as a member of the National Coal Board. The date and place of the opening of the inquiry, which will be in open court, will be announced later.

A SELF-ETCHING PRIMER.—A self-etching primer for all sorts of metals has been introduced by Donald Macpherson and Co., Ltd., of Church Road, Mitcham, Surrey, which combines a pre-treatment etch or pickle with the definition of a chromate corrosion-inhibiting film chemically bonded to the metal surface. This film provides a foundation for subsequent finishing coats and a bond between the metal and the finishing coat. Other than degreasing, metal articles need no special treatment before the application of the new primer, by either spraying or by brushing. The primer is mixed in set proportions and the mixture has to be applied within six to eight hours after preparation. Primed articles can be handled within fifteen to twenty minutes after application and are ready for top coating in an hour. "Foochaw" phosphor etch primer, as it is known by the makers, can be top-coated with all cellulose, oleo-resinous and synthetic resin based products of both air-drying and stoving types.

THE CHIEF PLANNING OFFICER.—In March, 1947, Sir Edwin Plowden was appointed Chief Planning Officer and chairman of the Economic Planning Board for a period of twelve months, a period which has since been several times extended with the concurrence of the companies of which Sir Edwin is a director. The Treasury has now announced that Sir Edwin will give up these appointments at the end of the present calender year. Sir Norman Brook, at present Secretary to the Cabinet, is to be transferred to the Treasury to carry out the duties at present performed by Sir Edwin Plowden.

RESEARCH FELLOWSHIPS.—A committee representing the Royal Society and the University of Sheffield has appointed Dr. B. A. Bilby as Sorby Research Fellow from October 1st, to work in the Metallurgy Department of the University of Sheffield on martensitic transformation and deformation twinning in crystals. Another committee, representing the Royal Society and the Armourers and Brasiers' Company, has appointed Dr. A. J. Kennedy as Armourers and Brasiers' Company Research Fellow from October 1st, to work at the Royal Institution of Great Britain on transient creep in polycrystalline metals.

OIL ENGINE FILM.—A film with the title of "The Diesel Story," has been added by the Shell Petroleum Company, Ltd., to its library of films dealing with oil. The film is in the form of a historical documentary and traces the development of the modern oil engine from the Otto gas engine, the hot bulb oil engine designed by Ackroyd Stuart and built in 1890, and the first engines of Dr. Diesel. The application of the diesel engine to marine work is recorded, the first ship to have this form of propulsion being the "Selandia," built in 1912. Animated diagrams explain the operations of the various cycles and the film concludes with views of a number of present-day applications of oil engine power. The running time is eighteen minutes and the film is available in 35mm and 16mm sizes.

A DESIGN CONGRESS.—The first international discussion by industrialists of their design policies will take place at the Royal College of Art, in London, on September 19th and 20th as an official event of the Festival of Britain. This "Design Congress" will be attended by about 250 invited guests, mainly chairmen, directors and managers from leading firms in Britain, Europe and the U.S.A. They will discuss the topic "Design Policy in Industry as a Responsibility of High Level Management." Small exhibitions of photographs and other material illustrating the design policies of the speakers' firms will be staged in the Royal College of Art, and a special exhibition of work by the College students will be shown to congress members. The congress has been planned by the Council of Industrial Design, which appointed a management committee with representatives from the Federation of British Industries, the Trades Union Congress, the Royal Society of Arts, the Society of Industrial Artists, and the Design and Industries Association.

THE CORROSION OF BURIED METALS.—A symposium on "The Corrosion of Buried Metals" is being organised by the Iron and Steel Institute, in co-operation with the British Iron and Steel Research Association and the Corrosion Group of the Society of Chemical Industry. It will be presented at the Institute's headquarters at 4, Grosvenor Gardens, London, S.W.1, on Wednesday, December 12th, in two sessions beginning at 10 a.m. and 2.30 p.m. At the morning session the following papers are to be discussed:—"Tests on the Corrosion of Buried Iron and Steel Pipes," by J. C. Hudson and G. P. Acock; "Investigations on Underground Corrosion," by K. R. Butlin, W. H. J. Vernon and L. C. Whiskin; "Cathodic Protection," by K. A. Spencer, and "Cathodic Protection of Buried Metal Structures," by M. R. de Brouwer. At the afternoon session, the papers for discussion are: "Corrosion of Buried Copper and Ferrous Strip in Natural and Salted Soils," by G. Mole, and "Tests on the Corrosion of Buried Aluminium, Copper and Lead," by P. T. Gilbert and F. C. Porter. Application forms for admission to the symposium can be obtained from the Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1.

Personal and Business

THE STAHLUNION COMPANY, Ltd., has moved to 61, Pall Mall, London, S.W.1.

THE RAILWAY EXECUTIVE announces the appointment of Mr. F. J. Pepper as executive officer (wagons) at headquarters.

TOWLER BROTHERS (PATENTS), Ltd., Rodley, Leeds, states that Mr. H. M. Mustill, secretary, and Mr. E. Jones, sales manager, have been appointed directors of the company.

THE LOCKHEED HYDRAULIC BRAKE COMPANY, Ltd., announces that Wing-Commander H. P. Powell is joining its staff to promote closer liaison between its aircraft division and the aircraft industry.

MR. I. S. HORABIN has been appointed sales manager of Scottish Mechanical Light Industries, Ltd., Scot Mec Works, Ayr. Mr. J. A. Culley has been appointed liaison officer to Scot Mec dealers.

THE CHANCELLOR OF THE EXCHEQUER has appointed Major C. R. Dibben, director of J. Brockhouse and Co., Ltd., to be chairman of the Midland Regional Board for Industry in succession to Mr. W. H. Stokes.

UNITED EBONITE AND LORIVAL, Ltd., Little Lever, near Bolton, states that Mr. G. F. Sly, chief designer, has been appointed assistant works manager. Mr. J. Kirkpatrick has been appointed chief designer.

MACROME, Ltd., Wolverhampton, states that Mr. R. A. Harding has been appointed general manager, and Mr. N. D. Pentland, sales manager. Mr. P. N. Rogers has been appointed directors' special representative.

MR. R. H. CHILTON, who for many years has been associated with I.C.I. (Alkali Division), Ltd., has joined the firm of G. F. Ward and Partners, consulting engineers, Old Colony House, South King Street, Manchester, as a partner.

THE MINISTRY OF CIVIL AVIATION announces that Mr. R. S. S. Dickinson has been selected to succeed Group Captain C. Clarkson, A.F.C., as Civil Air Attache at Washington. Mr. Dickinson will take up duty in this appointment at the beginning of 1952.

MR. F. M. OWNER, the chief engineer of the engine division of the Bristol Aeroplane Company, who has been with the company for twenty-two years, is leaving shortly and will be replaced by Dr. S. G. Hooker, deputy chief engineer of the company. Dr. Hooker joined the Bristol Aeroplane Company in 1949.

SIR JAMES SWINBURNE, F.R.S., chairman of Bakelite, Ltd., until 1948, has now retired from the board. He has been appointed honorary president of the company. Mr. P. Huffman, Mr. N. H. Docker, Mr. C. C. Last and Mr. G. W. Hodds have been appointed directors, the two last-named being joint general managers.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., announces that the telegraphic address of its Liverpool branch is now "Bicalbest, Liverpool, 1," and that the telephone number of its branch at 48, Stoke Road, Shelton, Stoke-on-Trent, has been changed to Stoke-on-Trent 44256. The telephone number of the B.I.C. Construction Company, Ltd., Clarence Chambers, Kingsway, Stoke-on-Trent, is now Stoke-on-Trent 44368.

THE BRITISH ELECTRICITY AUTHORITY announces the following appointments:—Mr. W. Wilde, B.Sc., A.M.I.Mech.E., A.M.I.E.E., chief generation engineer (operation) of the London Division, in succession to Mr. H. J. Bennett, A.M.I.E.E., who has been appointed Controller of the South Wales Division; Mr. R. E. Cornish, A.M.I.E.E., system operation engineer, Midlands Division; Mr. J. Whitfield, A.M.I.Mech.E., A.M.I.E.E., generation engineer (operation) in charge of No. 3 sub-division of the North-Western Division, in succession to Mr. O. S. Woods, who has been appointed chief generation engineer (operation), East Midlands Division; Mr. Ernest Long, secretary of the Authority, in succession to Mr. H. F. Carpenter, who is retiring.

Contracts

THE BURNTISLAND SHIPBUILDING COMPANY, Ltd., has contracted to build, for the Dundee, Perth and London Shipping Company, Ltd., a motor cargo vessel of 4650 tons deadweight having a length between perpendiculars of 315ft, a breadth of 47ft 10in and a depth of 26ft 3in. The propelling machinery will be a Doxford oil engine of 1900 b.h.p., constructed by the Ailsa Shipbuilding Company, Ltd.

British Patent Specifications

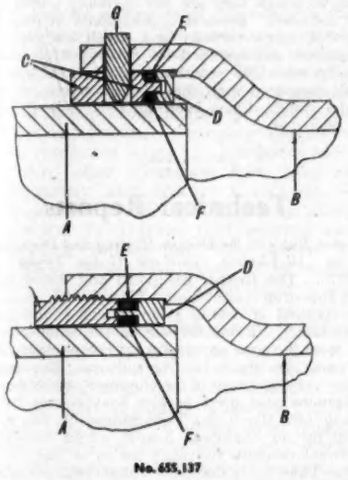
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.

TUBE AND PIPE COUPLINGS

655,137. September 2, 1948.—Pipe Joints Sealed or Secured by Fluid Pressure, John Geoffrey Dawes, "Lasan," 66, Crawford Road, Sheffield, 8.

The invention concerns a self-sealing pipe joint or ring system, which is simple in construction and inexpensive to manufacture. In the accompanying drawing the joint is shown between pipes *A* and *B*. The rigid rings *C* and *D* are made so that a continuous tongue of rectangular cross-section projects from the inner surface of one ring and engages in a groove of similar section in the face of the other ring. The opposing faces of the two rigid rings are prevented from direct contact by



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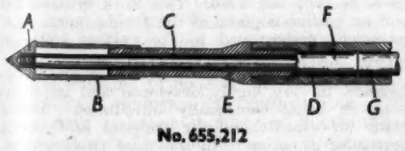
the two resilient rings *E* and *F*, one outside and the other inside the tongue projection on the ring *C*. The length of the tongue is such that whilst it locates the rings and mates freely with the groove, it is not of sufficient length to contact the bottom of the groove under compression. The shape of the resilient rings is such that they completely fill the two annular spaces which are formed when rings *C* and *D* are placed in position between the two pipes. The ring *C* is secured by means of three pegs *G* driven through the throat of pipe *B* and spaced at regular intervals around the circumference or by a screwed ring as shown in the lower view.—*July* 11, 1951.

CIVIL ENGINEERING

655,212. July 28, 1948.—Apparatus for Use in Determining the Bearing Capacity of Soil at Various Depths, The Nederlandsche Organisatievoor Toegepast-Natuurwetenschappelijk Onderzoek ten behoeve van Nijverheid, Handel en Verkeer, of 12, Koningskade, The Hague, Holland.

Referring to the drawing, the inverted conical pressure body *A* has formed on its base a tubular extension *B*, which is cylindrical on the inside and tapered on its outside. The extension fits around the tube extension *C*, which is connected to the lower end of the main tube *D* and has an inner diameter somewhat smaller than the inner diameter of that tube. The pressure body *A* is connected to a rod *E* with an enlarged upper part *F* acted upon by the rod *G*. When the apparatus is forced into the



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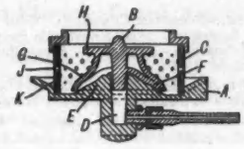
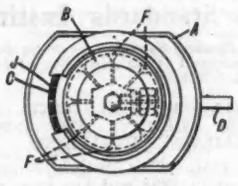
soil by means of the tube, the lower end of the tube rests on the base of the cone. The determination of the bearing capacity of a soil layer is then effected by forcing the cone into the soil by the rods *G* and *E*. During this motion the cone is guided by the tube and the cylindrical extension of the cone, so that the pressure body in its movement downwards cannot deviate from the perpendicular sounding-line. The stroke of the cone is limited by the length of the rod *E*, in the extreme lower position of the cone, the enlargement *F* abutting the circular upper part of the tube *C*. The length of the extension *B* is greater than the maximum stroke of the cone *A*, so that a soil-tight closure is ensured. The soil cannot expand and penetrate between the cone and the tube. By making the base diameter of the cone greater than the external diameter of the extension *B*, it is ensured that when the cone is forced down no adhesive force, which might impair the accuracy of measurement, acts upon the part *B*.—*July* 11, 1951.

BURNERS AND SPRAYERS

655,128. June 30, 1948.—Liquid-Fuel Burners, Speedfire Oil Burners, Ltd., 12, Railway Street, Chatham, Kent.

The burner illustrated comprises a cup or basin *A* surmounted by a body *B*, surrounded by a substantially vertical open-work or perforated wall *C*. A duct *D* for the supply of the fuel opens into the cup. The body stem fits in the opening of the duct and a cap portion is formed integrally with the stem. The fuel is directed by the duct to an elevated part *E* of the base at the centre of the cup below the cap portion of the body. The body *B* is supported by a number of webs *F*, which extend between the stem and the cap and bear on the surface of the elevated part *E* of the base, leaving wide intermediate spaces for the fuel and permitting the fuel to spread uniformly over the surface of the





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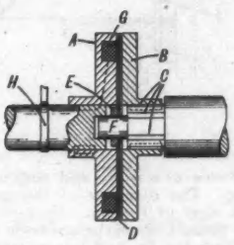
elevated part and of the base of the cup. The fuel discharge is controlled in such a manner that the thickness of the layer of fuel is relatively inconsiderable and as a result of this the fuel vaporises almost completely in passing between the elevated part *E* and the body *B*, which are heated by the burner flame, which is fed by the vapour thus obtained. When the burner is put into operation it should be preliminarily heated up. To effect the vaporisation of the fuel, the cap portion of the body *B* is shaped so that its lower surface extends substantially parallel to the surface of the part *E* and also to a part of the surface of the base of the cup where unvaporised fuel collects. The convex shaped upper surface *G* of the body rises in a direction substantially parallel to that of the flame when the burner is in operation. The body, which looks like a mushroom, is extended outwards at the top to form a flange *H* for augmenting the heat which the body can give up upon the passage of the vapour. The wall *C* has openings *J* permitting the passage of the combustion air. With the object of ensuring progressive combustion of the vapour, the lowest openings *K* are appreciably smaller than openings *J* above them.—*July* 11, 1951.

POWER TRANSMISSION

655,126. June 22, 1948.—Friction Clutches and Brakes, Autronic Developments, Ltd., Darlaston House, Warwick Road, Coventry (*Inventor: Ronald Job Elsome-Jones*).

As shown in the drawing, the clutch includes a disc-shaped electromagnet element *A*, keyed on a rotary shaft and a co-operating armature element *B* splined on a second rotary shaft as indicated at *C*. Between the clutch elements there is freely mounted a thin annular plate or disc *D* of magnetic material having a central annular bearing *E* of an appropriate metal such as brass, which rides freely on an extension *F* of the shaft. The extension is rotatable in a recess in the end of the other shaft so as to assist in maintaining coaxial alignment. The armature element *B*, like the plate *D*, is of high permeability magnetic material and is free to slide longitudinally on the splines *C* between its position of engagement and a shoulder formed on the shaft. The electromagnet element *A* has an annular winding *G* inset in its working face, and one end of this winding is connected by a conductor to an insulated slip-ring *H* for connection through a brush to a suitable current supply. The other end of the winding is connected to the energising circuit by way of earth return through the element *A* and the shaft. When the winding is energised the element *A* attracts the plate *D* and the armature



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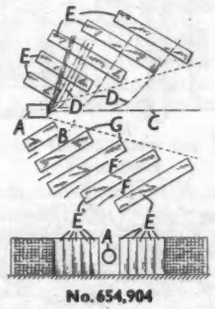
element *B*, and the latter moves a short distance along the splines so as to press the plate against the element *A* and permit torque to be transmitted from one clutch element to the other through the plate. The interposed plate is preferably of high permeability material and operates without creating a magnetic gap between the magnet and armature elements.—*July* 11, 1951.

AERONAUTICAL ENGINEERING

654,904. October 14, 1948.—Silencing of the Exhaust of Gas Turbine Engine Installations, Rolls-Royce, Ltd., of Nightingale Road, Derby (*Inventors: Frederick Reginald Murray and George Roland Gahagan*).

In the drawing, there is illustrated a gas-turbine engine exhaust nozzle *A*, from which the exhaust from the engine issues as a jet *B*. The exhaust jet in mixing with the atmosphere diverges at an angle of between about 10 deg. to 20 deg. The sound waves generated in the jet travel outwards from the jet axis *C* as indicated by the chain lines *D* and it will be seen that the maximum noise level occurs in a hollow cone of 80 deg. to 120 deg. apex angle. This cone is coaxial with the jet and has its apex substantially in the plane of the nozzle outlet. The noise level is indicated by the concentration of the chain lines. In order to reduce the noise level in the



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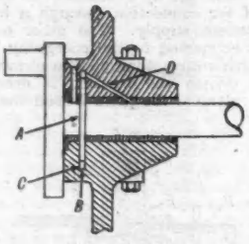
vicinity of the plant there is provided an arrangement comprising two sets of box-like baffles *E*, one on each side of the jet, approximately at right angles to the direction of propagation of the sound waves. As will be seen, the baffles of each set overlap one another lengthwise and are spaced from one another to leave air flow passages *F* between them. The baffles have their ends which are nearer the jet spaced from the jets as indicated at *G*, so as to permit a flow of cool air between the baffles *E* and the jet. These ends are spaced from the jet axis at successively greater distances to correspond to the divergence of the jet. With the arrangement described, the sound waves travelling along the lines *D* are intercepted by the baffle elements and a substantial proportion of the sound energy emitted by the jet is absorbed. The baffles may also be arranged with their lengthwise dimension parallel to the jet axis *C*. In other cases baffles may be provided to form a roof structure or the baffle structure may be of circular form to completely surround the jet. These two last modifications are illustrated in the specification.—*July* 4, 1951.

BEARINGS AND SUPPORTS

655,150. April 12, 1949.—Journal Bearings for Internal Combustion Engines, George Cecil Seymour, of "Kusaie," Kingston Lane, Southwick, Sussex.

As shown in the drawing, a journal bearing has, a short way along its length, a raised radial circular

projection or fin. This fin *A* may have radial grooves machined in its surface, and runs in a



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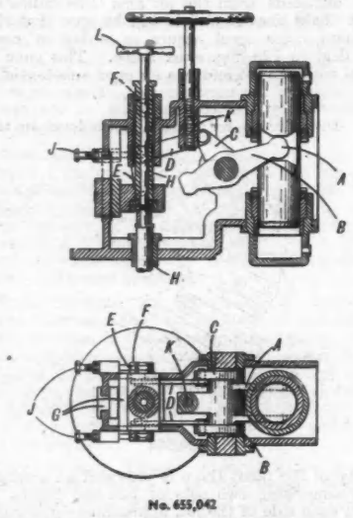
groove provided in the top and bottom halves of the bearing. The diameter of the groove *B* is larger than that of the fin. Upon rotating the shaft, oil is thrown by centrifugal force up into the space *C* above the fin and accumulates there at pressure, from whence it is led by any convenient passage *D* to other parts of the bearing surfaces. —*July* 11, 1951.

HYDRAULIC MACHINERY

655,042. November 26, 1947.—HYDRAULIC ACTUATING MECHANISMS, Hyland, Ltd., Doncaster Road, Wakefield, Yorkshire, and Harry Russell Clark, of the company's address.

This invention has for its chief object to provide a new or improved mechanism for transmitting the reciprocal movements of a hydraulically-operated piston or ram for actuating other mechanism. As illustrated in the drawings, the valve control mechanism comprises a hydraulically-operated double-ended piston having a cylinder at each end, the piston being recessed centrally to engage the forked or spaced arms *A* of a duplex bell-crank lever *B*. This lever is mounted upon a cross shaft in the casing and has further spaced arms *C* pivotally mounted on a link *D*, which is connected to further links *E* and *F* constituting a



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toggle mechanism. One pair of links *F* of the toggle mechanism is pivotally attached to a stationary part of the valve mechanism casing, whilst the other pair of links *E* of each toggle mechanism is attached to a cross head or collar *G* connected to the stem *H* of the steam valve. The arrangement of the toggle mechanism will be such that when the valve is closed the toggle mechanism has passed over the dead centre position as shown in the upper view. In this connection an adjustable stop *J* is provided to limit the movement of the toggle mechanism. A manual locking mechanism may be also provided for preventing actuation of the valve by the hydraulic mechanism and may take the form of a locking screw *K*, which engages a further arm on the bell-crank lever *B*. Provision is also made for hand operation of the valve stem *H* by means of a projecting handle *L*.—*July* 11, 1951.

FLOCCULATION PLANT.—A brochure on "Simcar" froth flotation and flocculation plants has now been made available by Simon Carves, Ltd., Stockport. The brochure is well illustrated and includes flow diagrams and performance characteristics of several typical plants designed for the treatment of coal slurry and for water clarification.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Institute of Road Transport Engineers

Tues., Aug. 28th.—Visit to the works of Vauxhall Motors, Ltd., Luton, Beds, 10.15 a.m.

The Royal Aeronautical Society

Mon., Sept. 10th.—Royal Institution, 21, Albemarle Street, W.1, 39th Wilbur Wright Memorial Lecture, "The Well-Tempered Aircraft," A. E. Raymond, Douglas Aircraft Corporation, 6 p.m.

Thurs., Oct. 4th.—Institution of Civil Engineers, Great George Street, S.W.1, Seventh British Commonwealth and Empire Lecture, "Air Transport in New Zealand and the South Pacific," Air Vice-Marshal Sir L. M. Isitt, R.N.Z.A.F., 6 p.m.

Stephenson Locomotive Society

Sat., Aug. 18th.—Visits to Motive Power Depots (London and Southern), Stratford, (North Eastern) Gateshead, (North Western) Bolton and Bury, (Scottish) St. Margarets, 2.30 p.m.

Sun., Aug. 19th.—Visit to Swindon Locomotive Works and Running Sheds, from 1.30 p.m.

Sat., Aug. 25th.—Lineside Traffic Observation, Bromsgrove and Lickey Incline, L.M. and W. Regions, from 2 p.m.

Sat., Sept. 1st.—SCOTTISH CENTRES: Tour by special train over routes not usually available for passengers, Paisley—Johnstone—Barrhead. Start Paisley (East Mineral) about 2.45 p.m.

Sat. Sept. 8th to Sun. Sept. 9th.—Week-end tour of Motive Power Depots in Swansea and South Wales area.

Sat., Sept. 15th.—Visit to Ashford Locomotive Works and Running Shed, S.R., from 2.45 p.m.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

ALTERNATING-CURRENT LINE RELAYS DOUBLE ELEMENT THREE-POSITION FOR RAILWAY SIGNALLING

No. 561 : 1951. This British Standard was first published in 1934 and has been revised as part of a general revision of British Standards for railway signalling relays. The standard applies to alternating-current line relays of the two-element, three-position induction type, for use on railway signalling circuits not exceeding 250V. Carbon-to-carbon contacts are no longer specified as they are not now generally used. The former minimum drop-away value of 80 per cent of the pick-up voltage has now been reduced as the result of specifying tolerances for contact alignment. A further change is that two standard types of contact equipment are now specified. Requirements are laid down relating to mounting, mechanical clearances, bearings, coils, contact capacity, contact pressure, contact resistance, flexible connections, terminals and terminal markings, insulation tests, pick-up and drop-away values, labelling and marking, finish and pointer scale. Price 2s., post free.

SOLID TAPER PINS AND SPLIT TAPER PINS FOR AERONAUTICAL PURPOSES

Nos. S.P. 28, 29 and 30 : 1951. These three standards deal with solid taper pins for aeronautical purposes, and Nos. S.P. 31 and 32 : 1951, deal with split taper pins for aeronautical purposes.

These recently published standards specify the materials, dimensions and finish of high tensile steel and (in the case of solid pins) aluminium alloy taper pins. Price 1s. each, post free.

CAST IRON SMOOTH TUBE ECONOMISERS WITH PRESSED SOCKET JOINTS

No. 1713 : 1951. This new British Standard covers cast iron smooth tube economisers with pressed socket joints having a maximum water design pressure up to and including 325 lb per square inch (gauge) where the socket joints are not reinforced, and a corresponding maximum pressure of 475 lb per square inch (gauge) where the socket joints are reinforced in accordance with the requirements of this standard.

In the section dealing with construction, formulæ are included for determining the design pressure for economiser sections with pressed socket joints, and the minimum thicknesses of headers, tubes and manifold pipes. Formulæ for determining flange dimensions and the number of bolts and studs to be used are also given. The minimum sizes of studs required for certain pressures are laid down and also the minimum lengths for the tapped holes. Installation requirements are specified, together with details of the mountings. Inspection during construction is also stipulated, together with details of hydraulic tests. Price 2s. post free.

B.A. SCREWS, BOLTS, NUTS AND PLAIN WASHERS

No. 57 : 1951. The publication of the revised edition of B.S. 57 confirms as a regular British Standard the War Emergency Standard published in 1944, subject to certain modifications, which more recent experience has shown to be desirable. General dimensions for all the common types of B.A. screws, bolts and nuts in sizes 0 B.A. to 16 B.A. are included and the ranges of nominal sizes given in the tables are classified as "preferred," "second choice" and "not normally stocked." Tables relating to each type of screw and showing the lengths in which each size is normally stocked and other lengths which may be regarded as standard, although they are not normally stocked, are also included. General requirements in respect of material, screw threads and finish are given and dimensions are specified for two types of washers. Finally, since the production of B.A. bolts is very small compared with that of B.A. screws, the title of the standard has been suitably revised. Price 3s., post free.

Technical Reports

Some Notes on the Design, Testing and Performance of an All-Electric, In-Sack Grain Dryer (Ref. IB/T5). The British Electrical and Allied Industries Research Association. Price 2s. 9d., post free. —A method of drying grain in sacks, one that is particularly suitable for use on the smaller farms, has recently been developed by the workers at the National Institute of Agricultural Engineering. In the various stages of development, an oil-burning equipment was used as the heat source for the drying air; the direct replacement of this equipment by an electrical heater would involve an electrical demand too high for most farm service lines. This report describes a successful experiment carried out on a farm during the 1950 harvest with the object of reducing the maximum demand of an electrically heated installation. In this instance the theoretical capacity required for the air heater was reduced from 23kW to 68 per cent of that value by adjustments to the rate of air flow and other factors.

Comprehensive tests were carried out during harvest by staff of the Ashford District of the South-Eastern Electricity Board and the results of these tests, together with recommendations for the design of any future installations, are included in the report.

Bituminous Roads in North America. Road Research Technical Paper No. 22. Dr. A. R. Lee. London: H.M. Stationery Office. Price 2s. 6d. The information given in this report is based on a tour of some 10,000 miles made by the author in the summer of 1949 and on visits to many American road laboratories. The road system in the U.S.A. is being improved and expanded at a speed vastly greater than anything possible elsewhere and new ideas and processes are being tried out on a large scale. Because of this rapid growth it has been necessary to develop methods of assessing the future financial requirements for maintenance and new construction of the varying types of surfacing used. This has involved complete and systematic examination of control sections up to 20 miles long over a period of years, and data so obtained has enabled reliable estimates to be made of the probable life of the surfaces; forecasts made in 1937 were thus borne out by the results of inspections in 1942 and 1946. This work is described and an outline is given of the various methods of pavement design used in the various states of U.S.A.

Mechanisation, both of construction and maintenance, is very highly developed and improved plant is being continually introduced. Mixing plant for asphalt and tar material is receiving particular attention; in the most modern types the contents of the mix are proportioned automatically and dust has been eliminated. The author refers to plans he made for co-operation with American workers for research into problems of adhesion and weathering and gives a clear account of bituminous road construction and research in the U.S.A.